RAZORBACK SUCKER STUDIES ON LAKE MEAD, NEVADA AND ARIZONA

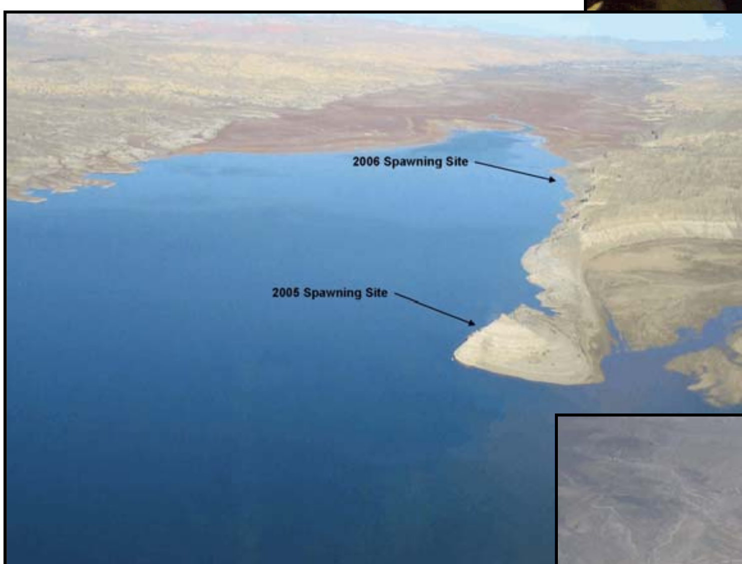
2005-2006 ANNUAL REPORT

PR-977-1

September 2006

Echo Bay spawning site selection, 1997–2006.

Wild sub-adult razorback sucker captured at Las Vegas Bay.



Muddy River/Virgin River inflow area presumptive spawning sites, 2005 and 2006.

Depiction of 2006 Las Vegas Bay spawning site with respect to Historical Point spawning area.

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EXECUTIVE SUMMARY

In 1996 the Southern Nevada Water Authority and the Colorado River Commission of Nevada, in cooperation with the Nevada Department of Wildlife, initiated a study to develop information about the Lake Mead razorback sucker (*Xyrauchen texanus*) population. BIO-WEST, Inc., under contract with the Southern Nevada Water Authority, developed the study design and had primary responsibility for conducting the study. The Nevada Department of Wildlife provided equipment, technical support, and field support for the project. Other agencies that joined as cooperators at the beginning of the study included: the U.S. Bureau of Reclamation, which provided funding for equipment, storage facilities, and technical support; the National Park Service, which provided residence facilities in their campgrounds; and the U.S. Fish and Wildlife Service, which assisted with permitting issues.

In November 2005, 10 adult fish obtained from Floyd Lamb State Park were implanted with 4-year sonic tags and stocked into Las Vegas Bay (5 fish), Echo Bay (2 fish), and the Muddy River/Virgin River inflow area (3 fish). Tagging was a collaborative effort between BIO-WEST, Inc., the Nevada Department of Wildlife, and the U.S. Fish and Wildlife Service. At the writing of this report, all but one of the Echo Bay fish have been contacted regularly since their release. Contact with the Echo Bay fish was lost within a week of its release, despite intensive, lake-wide telemetry contact efforts. Conversely, contact with the other sonic-tagged fish released into Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area enabled us to more precisely position net sets, identify larval sampling sites, and identify 2006 spawning areas, including our first documentation of a shift in spawning habitat use of the Las Vegas Bay population (from Blackbird Point to the southwestern shoreline of Las Vegas Bay). In addition to the 10 fish tagged this year, a telemetered fish from the 2004 tagging event was contacted throughout the Overton Arm, ranging from Echo Bay to several kilometers up the Muddy River. Future releases of sonic-tagged fish (particularly in conjunction with repatriation/stocking events) may be useful in further documenting and understanding razorback sucker habitat use dynamics throughout Lake Mead, tracking dispersal tendencies of repatriated fish, and locating new spawning areas, all while facilitating continued information collection about habitat use of the razorback sucker populations at known, traditional spawning sites.

Trammel netting for adult fish during the spawning period continued and 47 adults, including 13 from Las Vegas Bay, 31 from Echo Bay, and 3 from Fish Island (in the northernmost portion of the Overton Arm), were captured. Interestingly, three of the razorback sucker collected from Las Vegas Bay were subadult fish (greater than 300 millimeters in total length, yet sexually immature). Of the 47 total razorback sucker collected, 34 were recaptures; this recapture rate is similar to that of previous years. The most interesting new captures during the 10th study year were two of the adult fish captured along the Fish Island shoreline and the aforementioned subadult fish collected at Las Vegas Bay.

Another highlight of the 2005–2006 field season, in addition to the capture of three ripe, adult razorback sucker (one was a sonic-tagged fish introduced this season, one was an Nevada Department of Wildlife repatriate stocked into Echo Bay in 2002, and one was a wild, unmarked fish) via trammel netting at the Muddy River/Virgin River inflow area, was the capture of five larval razorback sucker at the same location. The information obtained from sonic telemetry, trammel netting, and larval sampling suggests that the Muddy River/Virgin River inflow area of Lake Mead is another important area for razorback sucker production and recruitment.

Average growth for this study year, as determined from 26 recaptured fish, was 10.6 mm. Mean annual growth of Las Vegas Bay fish was 21.6 mm, and 2.6 mm for Echo Bay fish. Growth rates of Lake Mead razorback sucker continue to be substantially higher than those recorded from other populations, suggesting that the Lake Mead razorback sucker populations are fairly young.

Small sections of fin rays were removed from 13 razorback sucker for age determination during the 10th study year, bringing the total number of fish aged during the study to 91. Of particular interest related to aging techniques was the documentation of recent (2000–2002) recruitment. Past collections and analyses identified recruitment through 1999; however, fin ray material obtained during the 2005–2006 study year from several subadult fish indicates continued, recent recruitment at Las Vegas Bay. Age-determination techniques continue to show that recruitment pulses in Lake Mead are associated with relatively high and stable lake elevations, with some steady, low-level recruitment occurring nearly every year.

In addition to the efforts and findings reported above, BIO-WEST, Inc., also worked collaboratively with biologists from the Nevada Department of Wildlife, the U.S. Bureau of Reclamation, and the Southern Nevada Water Authority in a renewed effort to collect additional larval razorback sucker for Lake Mead repatriation efforts. These newly collected fish will hopefully allow not only for increased razorback sucker presence in Lake Mead, but may also be useful in researching additional opportunities to test our hypothesis concerning lake levels, vegetative cover, and recruitment patterns during future study years.

As requested last season, efforts to locate and evaluate potential sites for repatriation and stocking efforts were expanded during 2005–2006. Two locations were identified as possible opportunities: Driftwood Cove and Grand Wash Bay. Both locations are proximal to the Colorado River and would, at higher lake elevations, be reconnected to the main body of the lake (although they are now cut off from Lake Mead proper). BIO-WEST, Inc., and collaborating agencies evaluated components of these sites with regard to potential repatriation and stocking efforts. The general consensus was that Driftwood Cove, although large, may provide the best opportunity for future stocking and repatriation activities.

The 2006 spawning period marks the first documentation of the Las Vegas Bay population spawning at a location different than the historical Blackbird Point site. Spawning has occurred along the southwestern shoreline of Las Vegas Bay as indicated by multiple adult captures, direct visual adult observation, relatively abundant larval densities, and heavy utilization of these habitats by newly introduced sonic-telemetered fish along this particular shoreline. It appears that the Las Vegas Bay razorback sucker population was able to shift spawning locations when the reservoir elevation fluctuated, similar to observations of the Echo Bay population during the majority of past study years. How this shift in spawning habitat use at Las Vegas Bay relates to future year class recruitment remains to be seen.

Similarly, during the last four spawning periods (2002–2005) at Echo Bay, the spawning site used the previous year was dry because of declining lake levels; however, each year this population found other suitable spawning sites in other portions of Echo Bay. During the 2006 spawning period, adult captures, visual adult observations, larval concentrations, and the habitat use of two telemetered fish indicated that the Echo Bay population spawned at a single location along the northern shoreline west of the Echo Bay Marina, at the same location used during the 2004 and 2005 spawning periods.

In addition to this annual report, a companion report will provide possible direction for long-term monitoring of Lake Mead razorback sucker populations. More specifically, data obtained during cumulative years of Lake Mead sampling will be used to generate information regarding the locations, methodologies, and in extracting temporal information that may be useful for a long-term monitoring effort of Lake Mead razorback sucker populations. It appears evident that there is utility in maintaining the long-term database developed by BIO-WEST, Inc. Answers to many questions about razorback sucker are likely to stem from data collected on Lake Mead, answers that would not likely be found without continued investigation of these unique populations.

Given the projected declines in lake levels expected to occur during the 2006–2007 field season, perhaps the lowest levels observed during the course of our studies, the general research objectives for the 2006–2007 study year include continuing to monitor the two populations of razorback sucker at Echo Bay and Las Vegas Bay, continuing to age individual razorback sucker from Lake Mead, and continuing to study razorback sucker use of the Overton Arm of Lake Mead. In addition to the general long-term data collection and monitoring effort, evaluation of Driftwood Cove will be emphasized (if desired by collaborators), and increased efforts may be made to analyze and review data from past years' research efforts.

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INTRODUCTION

The razorback sucker (*Xyrauchen texanus* [Abbott]) is an endemic fish species of the Colorado River Basin. It was historically widespread and common throughout the larger rivers of the Colorado River Basin (Minckley et al. 1991). The distribution and abundance of the razorback sucker are greatly reduced from historic levels, and it is one of four endemic, large-river fish species (Colorado pikeminnow [*Ptychocheilus lucius*], bonytail [*Gila elegans*], humpback chub [*Gila cypha*]) presently considered endangered by the U.S. Department of the Interior (USFWS 1991). One of the major factors causing the decline of razorback sucker and other large-river fishes has been the construction of mainstem dams and the resultant cool tailwaters and reservoir habitats that replaced a warm, riverine environment (Holden and Stalnaker 1975, Joseph et al. 1977, Wick et al. 1982, Minckley et al. 1991). Competition and predation from nonnative fishes that are successfully established in the Colorado River and its reservoirs have also contributed to their decline (Minckley et al. 1991). Razorback sucker persisted in several of the reservoirs that were constructed in the lower Colorado River Basin; however, these populations were comprised primarily of adult fishes that apparently recruited during the first few years of reservoir formation. The population of long-lived adults then disappeared 40 to 50 years following reservoir creation and the initial recruitment period (Minckley 1983). The largest reservoir population, estimated at 75,000 in the 1980s, occurred in Lake Mohave, Arizona and Nevada, but it had declined to less than 3,000 by 2001 (Marsh et al. 2003). More recently, Mueller (2005, 2006) reports the wild Lake Mohave razorback sucker population to be approaching 500 individuals. Adult razorback sucker are most evident in Lake Mohave from January through April when they congregate in shallow shoreline areas to spawn, and larvae can be numerous soon after hatching. Today, the Lake Mohave population is largely supported by periodic stocking of captive-reared fish (Marsh et al. 2003, Marsh et al. 2005). Predation by bass (*Micropterus* spp.), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), sunfish (*Lepomis* spp.), and other nonnative species appears to be the primary reason for lack of razorback sucker recruitment (Minckley et al. 1991, Marsh et al. 2003).

The Lake Mead population appeared to follow the trend of populations in other lower Colorado River Basin reservoirs. Lake Mead was formed in 1935 when Hoover Dam was closed, and razorback sucker were relatively common lake-wide throughout the 1950s and 1960s, apparently from reproduction soon after the lake was formed. Their numbers became noticeably reduced in the 1970s, approximately 40 years after closure of the dam (Minckley 1973, McCall 1980, Minckley et al. 1991, Holden 1994, Sjoberg 1995). From 1980 through 1989, neither the Nevada Department of Wildlife (NDOW) nor the Arizona Game and Fish Department (AGDF) collected razorback sucker from Lake Mead (Sjoberg 1995). This may be due in part to changes in their lake sampling programs; however, there was a considerable decline from the more than 30 razorback sucker collected during sportfish surveys in the 1970s. These results are not surprising and fit well within the pattern of razorback sucker population declines approximately 40–50 years following reservoir development, as was seen in other lower Colorado River Basin reservoirs.

After receiving reports in 1990 from local anglers that razorback sucker were still found in Lake Mead in two areas (Las Vegas Bay and Echo Bay), NDOW initiated limited sampling. From 1990 through 1996, 61 razorback sucker were collected, 34 from the Blackbird Point area of Las Vegas Bay and 27 from Echo Bay in the Overton Arm (Holden et al. 1997). Two razorback sucker larvae were collected by an NDOW biologist in 1995 near Blackbird Point, confirming suspected spawning in this area. In addition to the captures of these wild fish, NDOW also stocked subadult razorback sucker into Lake Mead. A total of 26 razorback sucker were stocked into Las Vegas Bay in 1994, and 14 were stocked into Echo Bay in 1995. All of these stocked fish were tagged with passive integrated transponder (PIT) tags, and all originated from the Dexter National Fish Hatchery 1984 year-class that was reared at Floyd Lamb State Park in Nevada. Collection of razorback sucker in the 1990s raised many questions about the Lake Mead population: How large is the population? Are the Las Vegas Bay and Echo Bay groups separate populations? Does razorback sucker recruitment occur in the lake? How old are the fish in Lake Mead, and are the two groups different in age structure? In 1996 the Southern Nevada Water Authority (SNWA), in cooperation with NDOW, initiated a study to attempt to answer some of these questions. BIO-WEST, Inc. (BIO-WEST), was contracted to design and conduct the study with collaboration from the SNWA and NDOW. Other cooperating agencies included: the U.S. Bureau of Reclamation (Reclamation), which provided funding, storage facilities, and technical support; the U.S. National Park Service (NPS), which provided residence facilities in their campgrounds; the Colorado River Commission of Nevada; and the U.S. Fish and Wildlife Service (USFWS).

At the start of the project in October 1996 the primary objectives were to:

- Determine the population size of razorback sucker in Lake Mead,
- Determine habitat use and life history characteristics of the Lake Mead population, and
- Determine use and habitat of known spawning locations.

In 1998 Reclamation agreed to contribute additional financial support to the project to facilitate fulfillment of Provision #10 of the Reasonable and Prudent Alternative generated by the USFWS's Final Biological and Conference Opinion on Lower Colorado River Operations and Maintenance-Lake Mead to Southerly International Boundary (USFWS 1997). In July 1998 a cooperative agreement between Reclamation and the SNWA was completed, specifying the areas to be studied and extending the study period into 2000. Additional study objectives added to fulfill Reclamation's needs, included the following:

- Search for new razorback sucker population concentrations via larval light-trapping outside the two established study areas, and
- Enhance the sampling efforts for juvenile razorback sucker at both established study sites.

If new populations were tentatively located by finding larval razorback sucker, trammel netting would be used to capture adults and sonic tagging would be used to determine the general range and habitat use of the newly discovered population. In 2002 Reclamation and SNWA completed another cooperative agreement to extend Reclamation funding into 2004. In 2005 a new objective of evaluating the lake for potential stocking options was added to the project as a response to a growing number of larval fish that had been and were slated to eventually be repatriated to Lake Mead. Most recently, Reclamation and SNWA have agreed to complete another cooperative agreement, tentatively extending research and monitoring efforts for the next several years.

This Annual Report presents the results of the 10th study year, from July 2005 through June 2006. Information and data from previous years (October 1996 to June 2005) are included where applicable.

SUMMARY OF EARLIER STUDY RESULTS, 1996–2005

Since the Lake Mead Razorback Sucker Study began in 1996, netting efforts have resulted in over 600 total razorback sucker captures, represented by 185 unique individuals that have been implanted with PIT tags. The PIT tags proved valuable in assessing growth and movement patterns for this population of razorback sucker. In 1997 four subadult razorback sucker were captured in Echo Bay, indicating that recent, natural recruitment had occurred within the Lake Mead population. An additional 13 wild subadult razorback sucker were captured in the Blackbird Point area of Las Vegas Bay through 2003. Beginning in 1999 small sections of fin rays were removed from wild razorback sucker for age determination purposes, and through 2005, 78 razorback sucker had been aged. The ages of collected adult fish ranged from 8 to approximately 35 years, and the subadult fish were between 4 and 6 years. It is believed that lake-level fluctuations that promote growth and then inundation of shoreline vegetation are largely responsible for the pattern of recruitment observed in Lake Mead's razorback sucker population. The inundated vegetation likely serves as protective cover, which, along with turbidity, allows young razorback sucker to avoid predation by nonnative fishes.

The declining and low lake elevations during the last several years have affected razorback sucker spawning sites at Echo Bay and the Colorado River inflow area of Lake Mead. At Echo Bay from 1997–2001, aggregations of sonic-tagged adults, redd location, and larval concentrations indicated that spawning was occurring at the back of Echo Bay along the south shore. Specifically, it appeared that adult razorback sucker were spawning at the base of a 50-foot-high cliff. At the end of the spawning season in May 2001, this site was dry. As the lake level continued to decline during the last several years, the Echo Bay population continued to find new spawning sites in Echo Bay as sites from previous years were dry, moving down the wash with the declining lake. At Las Vegas Bay during the first 9 years of this study, most razorback sucker larvae were captured along the western shore and tip of Blackbird Point. This suggests that the same portion of Blackbird Point was used for spawning every year, but the depth in this area changed dramatically as lake levels dropped. In the late 1990s, at a high lake elevation, the spawning location was thought to be near a depth of 80 feet. By 2003 the spawning depth was closer to 20 feet, and by the end of 2004 the area was completely desiccated. As a result, spawning was not observed at the Blackbird Point spawning area during the 2003–2004 study year, and only four larval razorback sucker were captured during the entire season at Las Vegas Bay, a site that harbored the largest razorback sucker population in Lake Mead. However, during 2005 spawning (January through April), Lake Mead elevations rose more than 20 feet, allowing access to the Blackbird Point spawning site during the ninth study year.

In 2000 and 2001 larval razorback sucker were captured in the Colorado River inflow region of Lake Mead. During the 2002 and 2003 spawning periods no larval razorback sucker were captured in this area. This population either did not spawn, or spawning took place outside of our sampling area. Alteration of spawning sites resulting from lake elevation changes may be responsible for the apparent absence of spawning in the Colorado River inflow region. In 2003–2004 larval sampling was conducted at the Muddy River/Virgin River inflow areas and throughout the Overton Arm of Lake Mead. Despite having habitat characteristics similar to Echo and Las Vegas Bays (in terms of turbidity, vegetation, and gravel shorelines), no larval razorback sucker were captured in the Overton Arm north of Echo Bay on any of the sampling occasions. However, after following movements of a single, sonic-telemetered fish in 2005, adult and larval sampling was reinitiated at the Muddy River/Virgin River inflow areas. The result of this effort was the capture of 2 wild, unmarked adult razorback sucker and more than 40 larvae from the Fish Island area, warranting further research in this portion of Lake Mead.

During the first 6 years of this study, 46 fish (42 wild and 4 hatchery reared) were equipped with internal or external sonic tags. Approximately half of these tags had a 12-month battery life (implanted in 1997 and 1998), and the other half had a 48-month battery life. Sonic telemetry showed a seasonal habitat use pattern within the lake. At Las Vegas Bay the fish concentrated in the Blackbird Point area during the spawning period but moved further out into the bay during the nonspawning period (June–November). Most of these fish were found using the north shore of Las Vegas Bay between Blackbird Point and Black Island. At Echo Bay a similar pattern was seen; fish left the Echo Bay spawning area and regularly used Rogers Bay and other points north of Echo Bay along the western shore of the Overton Arm. The four hatchery fish implanted with sonic tags and stocked into the Colorado River inflow area during the sixth study year were active in the Grand Wash Area for several months after stocking early in 2002. Two of the fish became stationary and the remaining two fish were last contacted in the inflow area in April 2002. Despite numerous lake-wide searches, the missing fish have not been located. In January 2003 (seventh study year) four razorback sucker (two at Echo Bay and two at Las Vegas Bay) were captured during standard trammel netting and implanted with 48-month sonic tags. One of the Las Vegas Bay fish was found stationary near Black Island in February 2003. The other fish and one of the Echo Bay fish were last contacted in 2003 (the eighth study year). The last fish from the 2003 telemetry implantation effort to be contacted was one of the Echo Bay fish, which was contacted several times during the early part of the 2004–2005 field season.

The drastic decline in larval fish abundance in 2004 spurred questions pertaining to if/where the Las Vegas Bay population was spawning. Welker and Holden (2004) proposed tagging six razorback sucker from Floyd Lamb State Park as an experimental test in hopes that the newly tagged fish would integrate with the wild population in Las Vegas Bay and help to identify new spawning areas. As a result, during the 2004–2005 study year, six fish from Floyd Lamb State Park were tagged, and sonic surveillance of these individuals produced interesting results. All contact with the four fish introduced into the Las Vegas Bay area was lost within 1 month. It is most probable that the tags failed, as multiple and extensive searches of the lake for the missing fish have been unsuccessful. However, two of the fish (experiencing the same surgery, handling, introduction, and monitoring protocols as the four Las Vegas Bay fish) were introduced at Echo Bay. In general, these fish appeared to integrate with the wild population and were followed throughout the 2004–2005 study year. One of these fish (code 344) spent the majority of the field season in the back of Echo Bay, while the other fish (code 222) displayed large movement patterns from Echo Bay and within the Overton Arm of Lake Mead. This report contains movement information for only one of the 2004–2005 tagged fish (code 222 from Echo Bay), which was contacted multiple times during the 10th study year. The sonic telemetry data collected during the first 9 years of this study have provided valuable information on razorback sucker spawning, movement patterns, and habitat use. Furthermore, it has been demonstrated that tracking even hatchery-reared, sonic-tagged razorback sucker can be highly effective in locating new spawning areas and monitoring known spawning locations used by wild razorback sucker populations.

STUDY AREAS

All of 2005–2006 study year activities occurred at the locations used in the 1996–2005 portions of the study (Holden et al. 1997, Holden et al. 1999, Holden et al. 2000a, Holden et al. 2000b, Holden et al. 2001, Abate et al. 2002, Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005). The two most familiar areas sampled were Echo Bay and Las Vegas Bay (Figure 1). Razorback sucker activity was also studied at the Muddy River/Virgin River inflow area of Lake Mead, the portion of Lake Mead near Fish Island in the northernmost portions of the Overton Arm (Figure 1). During the 2005–2006 field season, sampling at the Colorado River inflow region of the lake was limited to investigating potential options for future stocking/repatriation efforts. Sonic telemetry was conducted lake wide and was a major focus of the efforts this year.

All areas of the lake, including the Overton Arm, Boulder Basin, Virgin Basin, and Colorado River inflow areas, were covered multiple times with telemetry equipment. Larval sampling was performed in Echo Bay, Rogers Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area. Trammel netting was conducted at Las Vegas Bay, Echo Bay, Rogers Bay, and at the Muddy River/Virgin River inflow area (Figure 1).

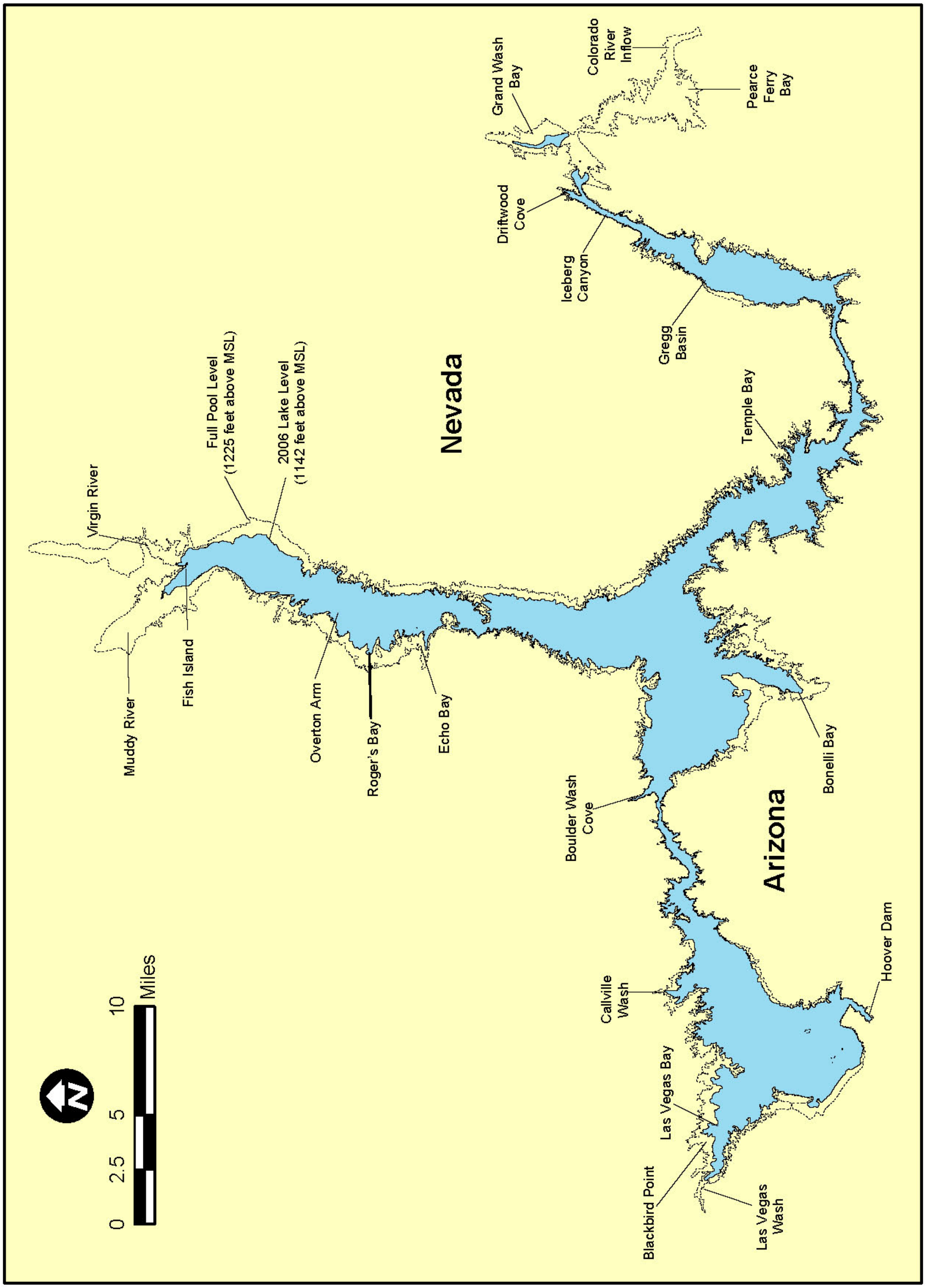

Figure 1. Map of Lake Mead showing general study locations.

Specific definitions for the various portions of the Las Vegas Wash/Bay in which the study was conducted were given in Holden et al. (2000b). These definitions are still accurate for various portions of the wash and are as follows:

- Las Vegas Wash is the portion of the channel with stream-like characteristics. This section is usually relatively narrow with obvious banks.

- Las Vegas Bay begins where the flooded portion of the channel widens and the velocity is reduced. Las Vegas Bay can have a flowing (lotic) and a non-flowing (lentic) portion. The flowing portion is typically short (200 to 400 yards) and transitory between Las Vegas Wash proper and Las Vegas Bay. Since lake elevation affects what is called the wash or bay, the above definitions are used to differentiate the various habitats at the time of sampling.

Throughout the text of this report, three portions of Las Vegas Bay may be referred to using the following terms:

- Flowing portion (the area closest to Las Vegas Wash).

- Non-flowing portion (usually has turbid water but very little current).

- Las Vegas Bay (the majority of the bay that is not immediately influenced by Las Vegas Wash and is lentic in nature).

Additionally, the location of wild adult and larval razorback sucker in the northern portion of the Overton Arm necessitates a description of these areas. The location definitions follow those provided in Albrecht and Holden (2005) and are as follows:

- Muddy River/Virgin River inflow area (the lentic and littoral habitats located between the Muddy River confluence and the Virgin River confluence with Lake Mead).

- Fish Island (located between the Muddy River and Virgin River inflows, bounded on its western side by the Muddy River inflow and on its eastern side by the Virgin River inflow, this area may or may not be an actual island depending upon lake elevation).

- Muddy River and Virgin River proper, the actual flowing, riverine portions that comprise the Muddy and Virgin rivers.

And lastly, this season's efforts at Driftwood Cove can be defined as occurring in:

- Driftwood Cove proper, the cove/bay that at higher lake levels is located directly at the back of Iceberg Canyon, prior to the historic river channel bend into the Grand Wash/Pearce Ferry Bay area. This location may or may not be an actual isolated bay depending upon lake level and river channel conditions. However, at the time of investigation, Driftwood Cove was slightly connected to the Colorado River, via a small (0.5 m wide by 15 cm deep) channel. It is hypothesized that the bay would totally disconnect from the river at a lake elevation of approximately 1,135 ft above mean sea level (amsl).

METHODS

Lake Elevation

Month-end lake elevations for the 2005–2006 field season (July 1–June 30) were measured in feet amsl and obtained from Reclamation's Lower Colorado Regional Office website (Reclamation 2006). The effect of fluctuating lake levels on razorback sucker habitat was documented by written observations and/or photographs during sampling trips to each of the study areas. Projected lake elevations related to Driftwood Cove investigations were also obtained from Reclamation (2006) and were further evaluated through on-site visits, pictures, maps, and GIS techniques.

Adult Studies

Trammel nets were the primary adult sampling gear (300 feet long by 6 feet deep with an internal panel of 1, 1.5, or 2 inches mesh and external panels of 12-inch mesh). Nets were generally set with one end near shore in 10–30 ft of water, with the net stretched out into deeper areas. All trammel nets were set in the late afternoon (just before sundown) and pulled the next morning (shortly after sunrise). Sampling was generally conducted weekly within each study area from January through May, with variable effort between months and locations. Netting locations for the three primary study sites were selected based on the locations used by sonic-tagged fish, the location of larval concentrations, and ancillary knowledge of historical spawning areas.

Fish were taken from the nets, and live fish were held in large, water-filled containers. Razorback sucker were isolated from other fish species and held in separate containers. All but the first five common carp were enumerated and returned to the lake, while other species (including five carp) were identified, measured for total length (TL), weighed, and released at the location of capture. Razorback sucker were scanned for PIT tags, tagged with PIT tags if they were not recaptured fish, measured (including standard length [SL] and fork length [FL]), weighed, and released at the point of capture. Razorback sucker were anesthetized with MS-222 and then placed dorsal side down on a padded surgical cradle for support during processing.

Larval Sampling

Larval sampling methods followed those developed by Burke (1995) and other researchers on Lake Mohave. The procedure utilizes the positive phototactic response of larval razorback sucker to capture them. After sundown two 12-volt "crappie" lights were connected to a battery, placed over each side of the boat, and submerged in 4 to 10 inches of water. Two "netters," equipped with long-handled aquarium dip nets, were stationed to observe the area around the lights. Larval razorback sucker that swam into the lighted area were dip-netted out of the water and placed into a holding bucket. The procedure was repeated for 15 minutes at each location, and 6 to 12 sites were customarily sampled on each night attempted. Larvae were identified and enumerated as they were placed in the holding buckets and then released at the point of capture when sampling at a site was completed.

As a result of fluctuating lake levels, larval sampling during spring 2006 could not be conducted at the same 12 Echo Bay and Las Vegas Bay standard larval sites that were sampled in spring 1999, 2000, and 2001 (Holden et al. 2000a, 2000b, 2001). During 2002–2006 only some of the original sites were used, and others were assigned based on initial sampling. Additional larval sites were selected at random to help locate spawning areas. When possible, the locations of 11 active, sonic-tagged fish and the previous week's adult netting results were also used to select larval sites over the course of the season. At Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area, larval sampling sites changed throughout the course of the season due to the ever changing desiccation and inundation of sites over the course of the study year. As a result, the larval sampling strategy was a much more responsive, fluid, and adaptable protocol than had been employed in the past. This strategy was useful in coping with fluctuating lake elevations during the course of the 2005–2006 study year.

In addition to the standard larval sampling conducted this year, BIO-WEST also worked collaboratively with biologists from NDOW, Reclamation, and SNWA in an effort to collect additional larval razorback sucker for future repatriation efforts. The general collection protocol was essentially an extension of the larval sampling BIO-WEST had developed (described above) with additional effort (time, boats, number of lights, etc.) spent collecting larval fish at specific sites, where catch per unit effort (CPUE) was elevated during a particular night. BIO-WEST and SNWA personnel worked under the direct supervision of agency biologists, and larval razorback sucker were immediately turned over to NDOW and Reclamation biologists upon capture for transport and hatchery provisions. Larval fish capture results stemming from the collaborative sampling efforts discussed above are not included as part of this report; they are retained by and available from NDOW upon request.

Age Determination

During the course of the 2005–2006 study year, selected razorback sucker captured via trammel netting were anesthetized, and a single, approximately 0.25-inch-long segment of the second left pectoral fin ray was surgically removed. Fish were anesthetized with a lake water bath containing MS-222, NaCl, and slime coat protectant to reduce surgery-related stresses, speed recovery, and avoid accidental injury to fish that may thrash about during the surgery. During the surgery, standard processing was accomplished (weighing, measuring, PIT-tagging) and a sample was surgically collected using sterilized bone snips. The connecting membrane between rays was cut using a scalpel blade, and the section was placed in a labeled envelope for drying. The surgical tool used to remove fin rays was developed by BIO-WEST; it is essentially a matched pair of finely sharpened chisels welded to a set of Vise-Grips™. All surgical equipment was sterilized before use, and subsequent wounds were packed with antibiotic ointment to minimize post-surgical bacterial infestations and promote rapid healing. All razorback sucker were immediately placed in a recovery bath of fresh lake water containing slime coat protectant, allowed to recover, and released as soon as the fish regained equilibrium and appeared recovered from the anesthesia. Vigilant monitoring of the fish was conducted during all phases of the procedure.

In the laboratory, fin ray segments were embedded in thermoplastic epoxy resin and heat cured. This technique allowed the fin rays to be perpendicularly sectioned using a Buhler isomet low-speed saw. Resultant sections were then mounted on microscope slides, sanded, polished, and examined under a stereo-zoom microscope. Oil immersion techniques were also used on occasion to increase clarity and aide in proper specimen age identification. Each sectioned fin ray was aged by at least two readers. Sections were then read a second time (by the readers) in instances where the assigned age was not under agreement. If age discrepancies remained after the second reading, the readers viewed the structure together and assigned an age. For further information regarding the evolution of our fin ray aging technique, please refer to Albrecht and Holden (2005), as well as other, past annual reports.

Sonic Tagging

Sonotronics Model CT-82-3-I (48-month) tags were implanted in four male and six female adult razorback sucker from Floyd Lamb State Park. Tagging events took place November 29–30, 2005, and tags were used to monitor razorback sucker movements and habitat selection during the 2005–2006 field season. The 48-month tags had an air weight of 24 g (8 g water weight) and measured 62 mm long by 16 mm in diameter. The tags used frequencies of 69, 70, 71, 72, and 73 kHz. Since each tag has a unique code, individual fish could be distinguished. The following surgical protocol was established from procedures developed by Valdez and Nilson 1982), Kaeding et al. (1990) and Valdez and Trinca (1995) for humpback chub; Tyus (1982) for Colorado squawfish (pikeminnow); and Valdez and Masslich (1989) for Colorado squawfish (pikeminnow) and razorback sucker. A transmitter air weight to fish weight of 2% (Bidgood 1980, Marty and Summerfelt 1990), was used to assure that the tags were not too large for the fish being tagged. Surgical implants were performed on shore. Three people were involved in the surgery, a surgeon and two assistants. The assistants took data, captured pertinent photographs, and monitored fish respiration. A highly specialized surgeon, Dr. Chris Bunt of BIOTACTICS, Inc., was contracted to assist, demonstrate current surgical practices, and instruct on updated tagging methodologies (tagging surgeon from previous study year). Direct supervision by BIO-WEST staff occurred during all stages of the surgical procedure. In addition to Dr. Bunt, USFWS biologists, NDOW biologists, and the rest of the BIO-WEST team were responsible for ensuring that all aspects of the surgical procedure were properly attended to.

Prior to surgery each fish was placed in a live well with fresh pond water. All surgical instruments were cold-sterilized with iodine and 90% isopropyl alcohol and allowed to air dry on a disposable sterile cloth. Razorback sucker were initially anaesthetized in 30 L of pond water with a 50 mL L^{-1} clove oil/ethanol mixture (0.5 mL clove oil [Anderson et al., 1997] emulsified in 4.5 mL ETOH). After anaesthesia was induced (post-opercular movement cessation), total length, fork length, standard length, and weight were recorded. Fish were then placed dorsal side down on a padded surgical cradle for support during surgery. Head and gills were submerged in 20 L of fresh pond water with a maintenance concentration of 25 mL L^{-1} clove oil/ETOH anaesthetic (Bunt et al. 1999). Following fish introduction to the maintenance anaesthetic, a 3–4 cm incision was made by the surgeon. The incision was positioned on the left side, immediately on the inside of the ribs but slightly towards the midline of the fish, and approximately 1.5–2.0 mm posterior of the left pectoral fin origin. The sonic transmitter was inserted through the incision and pushed back to rest on the pelvic girdle. The incision was closed with 3–4 sutures using 3-0 Maxon absorbable polygluconate monofilament suture with an attached PH 26 curved cutting needle. Surgery times typically ranged from 3–8 minutes per fish.

Fish were allowed to recover in a live well containing fresh pond water (until equilibrium was maintained), transferred to portable net pens within the pond, and monitored for approximately 2 hours. Fish were then held in aerated tanks provided by NDOW during transport from Floyd Lamb State Park to release points in Las Vegas Bay, Echo Bay, and the Muddy River/Virgin River inflow area. Upon arrival at the desired release points, fish were re-examined for signs of stress and then slowly acclimated to Lake Mead water temperatures prior to release. Tracking and movement monitoring ensued immediately after release and continued intensively for 48 hours, followed by detailed tracking in the days and weeks following (see Sonic Tracking section below).

Sonic Tracking

Sonic telemetry was utilized to assess adult habitat use and movement within and between spawning areas. Four male and six female razorback sucker from Floyd Lamb State Park were sonic tagged during the 2005–2006 field season. Telemetric methodology was also incorporated to follow a single, residual fish from the 2004–2005 tagging event described in Albrecht and Holden (2005). Fish were located on a weekly basis or more frequently, depending on the field schedule and weekly goals of the project. Searches for fish were generally made along shorelines with listening points every 0.5 mile or less, depending on shoreline configuration and other factors that could affect the ability to hear a signal. Since sonic equipment is line-of-sight, any obstruction can reduce or block a signal. Once a signal was found, the directional capabilities of the hydrophone, volume of the transmitter, and triangulation techniques were used to pinpoint the actual location of the fish, which was then noted using a GPS unit. At the time of introduction of the 10 newly tagged fish, daily monitoring of habitat use and movements was intensively conducted (for approximately 1.5 months), as fish tagged and subsequently introduced into new environments have been documented to cover vast amounts of distance in relatively short time frames (Mueller et al. 2000).

Population Estimates

Capture data collected by BIO-WEST from 2004–2006 were used to calculate abundance estimates for razorback sucker populations at Echo Bay and Las Vegas Bay. Stocked fish were not used in the population estimates unless they had survived at least 1 year in Lake Mead. It was hypothesized that an adult stocked fish that had survived 1 year in the wild was able to reproduce and contribute progeny to the population (Albrecht and Holden 2005, Modde et al. 2005). Estimates for both populations were derived from the most recent 3-year data collection period (2004–2006) of this study.

Two abundance estimators were used, Chao's M_h (Chao 1989) and Model M_o (Otis et al. 1978). The Model M_o typically produces the most reliable estimates for endangered western fishes (Dr. Ron Ryel, consultant, personal communication), but it assumes equal catchability of individuals. Chao's M_h is a good estimator for sparse data, but unlike Model M_o it assumes heterogeneity of capture probabilities. If the estimators gave very different numbers, then a reliable estimate was believed to lie somewhere between the two numbers. However, as shown in past reports, close agreement between the two models indicated a fairly reliable estimate.

Potential Stocking/Repatriation Opportunities and Locations

One of the objectives specified in Albrecht and Holden (2005), pertaining to the 10th study year, was to identify potential sites for future stocking/repatriation efforts and locate areas that might be conducive to establishing new razorback sucker spawning populations within Lake Mead. As a result, a portion of our efforts were expended during 2005–2006 field season to identify potential locations and areas of possible opportunity for future stocking/repatriation activities. Using knowledge of Lake Mead and information regarding Lake Mead razorback sucker populations gleaned from past study years, a fixed-wing aircraft was utilized to look for areas that might serve as potential opportunities for repatriation/stocking efforts. During these initial flights, two locations were identified near the Colorado River inflow that displayed habitat characteristics such as turbidity and proximity to vegetative cover. These areas were temporarily isolated or could potentially be isolated from the lake, and provide potential for manipulation of nonnative predators/competitors. This potential is hypothetically important for successfully initiating a new population, if/when deemed appropriate by collaborating agency personnel. Following the identification of these two locations, ground surveys of the areas ensued. Potential areas were investigated to determine size, water quality, fish community composition, connectedness to the river, substrate composition, overall depth, and the general logistics involved with gaining access to the potential sites. Both qualitative and quantitative evaluations of the aforementioned items were obtained during two ground surveys of the locations, and the results of these visits are provided below.

RESULTS

Lake Elevation

As opposed to the ninth study year, lake elevations during the 10th study year can be described as diminishing overall. From a starting elevation in July of 1,139 ft amsl, lake levels dropped to a November month-end lake elevation of 1,137 ft amsl. This slight drop was followed by a nominal increase in lake elevation during December, January, and February reaching a season high-level mark of nearly 1,141 ft amsl, an average increase of approximately 2 ft per month. Following this slight increase in lake elevation during the initial part of the spawning period, lake levels again began to diminish, reaching a month-end lake elevation of 1,131 ft amsl by late May. This translated to an overall loss of 11 ft (or over 3 ft of loss on average per month) during the latter portion of the spawning season (Figure 2).

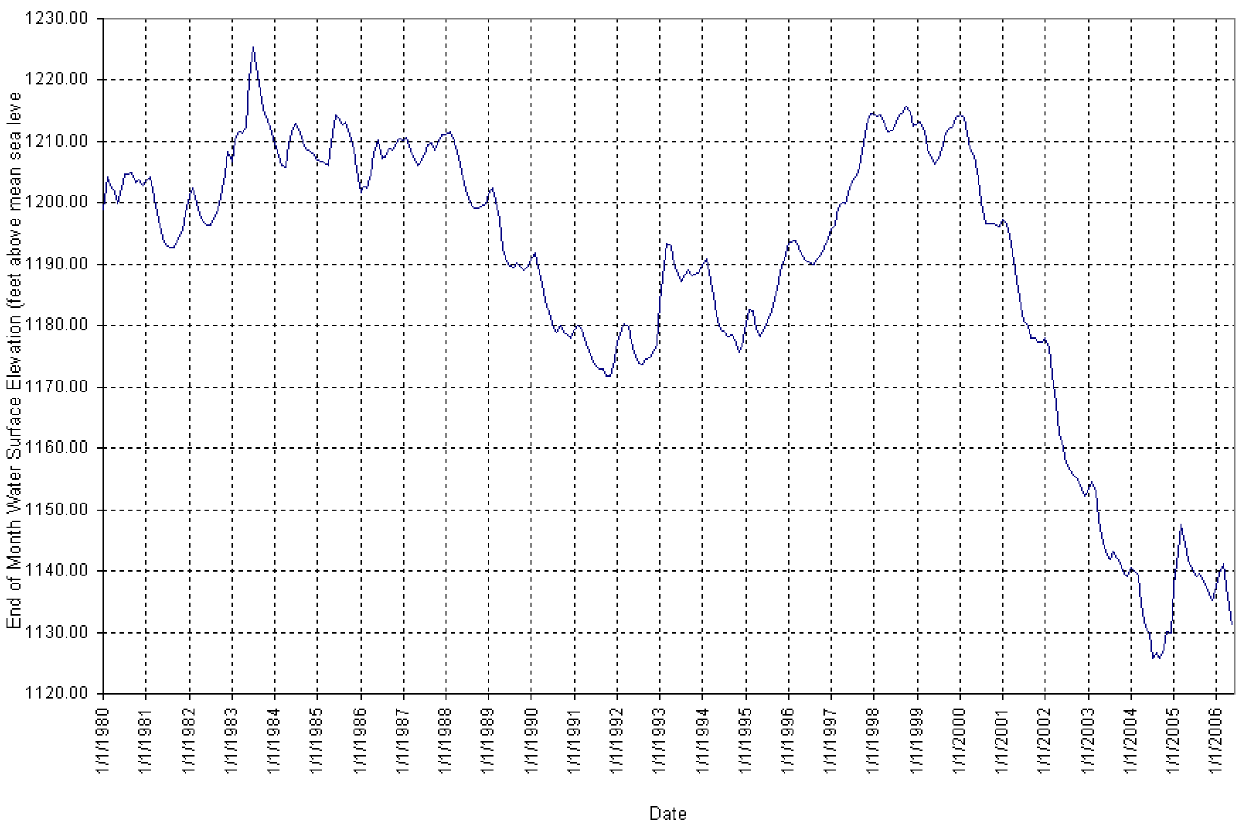

Figure 2. Lake Mead month-end lake elevations, January 1980 through June 2006.

Adult Sampling

Trammel Netting

Table 1 shows the trammel netting effort, expressed as net nights, that occurred from July 2005 to June 2006. Figures 3, 4, and 5 show the locations of trammel net sets in the primary study areas for the same period. One net night is comprised of a single net, set overnight. Trammel netting was conducted over 133 net nights during the 10th study year, with 44 net nights spent in the Las Vegas Bay/Boulder Basin area, 49 net nights spent in the Echo Bay area, and 40 net nights accumulated at the Muddy River/Virgin River inflow area. Trammel netting effort was concentrated along the western shoreline area in Las Vegas Bay, as well as near Blackbird Point (Figure 3). Netting was also conducted near the flowing and nonflowing portions of Las Vegas Bay, primarily near the back of Echo Bay (Figure 4). In all cases, net sets were largely dictated by the location of sonic-tagged fish in each of the sampling areas.

Table 1. Trammel netting effort (net nights) on Lake Mead during the 10th study year.

MONTH	LAS VEGAS BAY/ BOULDER BASIN	ECHO BAY	OVERTON ARM	TOTAL
January	8	4	6	18
February	9	14	13	36
March	14	16	14	44
April	11	12	7 [a]	30
May	2	3	-	5
June	-	-	-	0
Total	**44**	**49**	**40**	**133**

[a] Three net sets from Rogers Bay, not Muddy River/Virgin River inflow area.

Trammel netting at the Muddy River/Virgin River inflow was concentrated around the Fish Island shoreline, but efforts were designed to be flexible and were largely dictated by the habitat use and movements of sonic-tagged fish throughout the northern portions of Lake Mead. As such, sampling occurred even within the lower portions of the Muddy River proper (Figure 5). Most of the netting effort was expended from January through the end of April (Holden et al. 1997, 1999). During the 2005–2006 field season, adult razorback sucker were captured at depths ranging from 4–22 feet, with a mean capture depth of 14 feet (averaged across all netting and razorback capture locations).

No trammel netting effort specific to razorback sucker was expended at the Colorado River inflow area during the 10th study year. However, at Driftwood Cove (see subsequent sections) limited gill netting effort was expended to ascertain the nonnative species composition during a multiagency collaborative field trip and site visit during May 2006. No razorback sucker were collected during this effort.

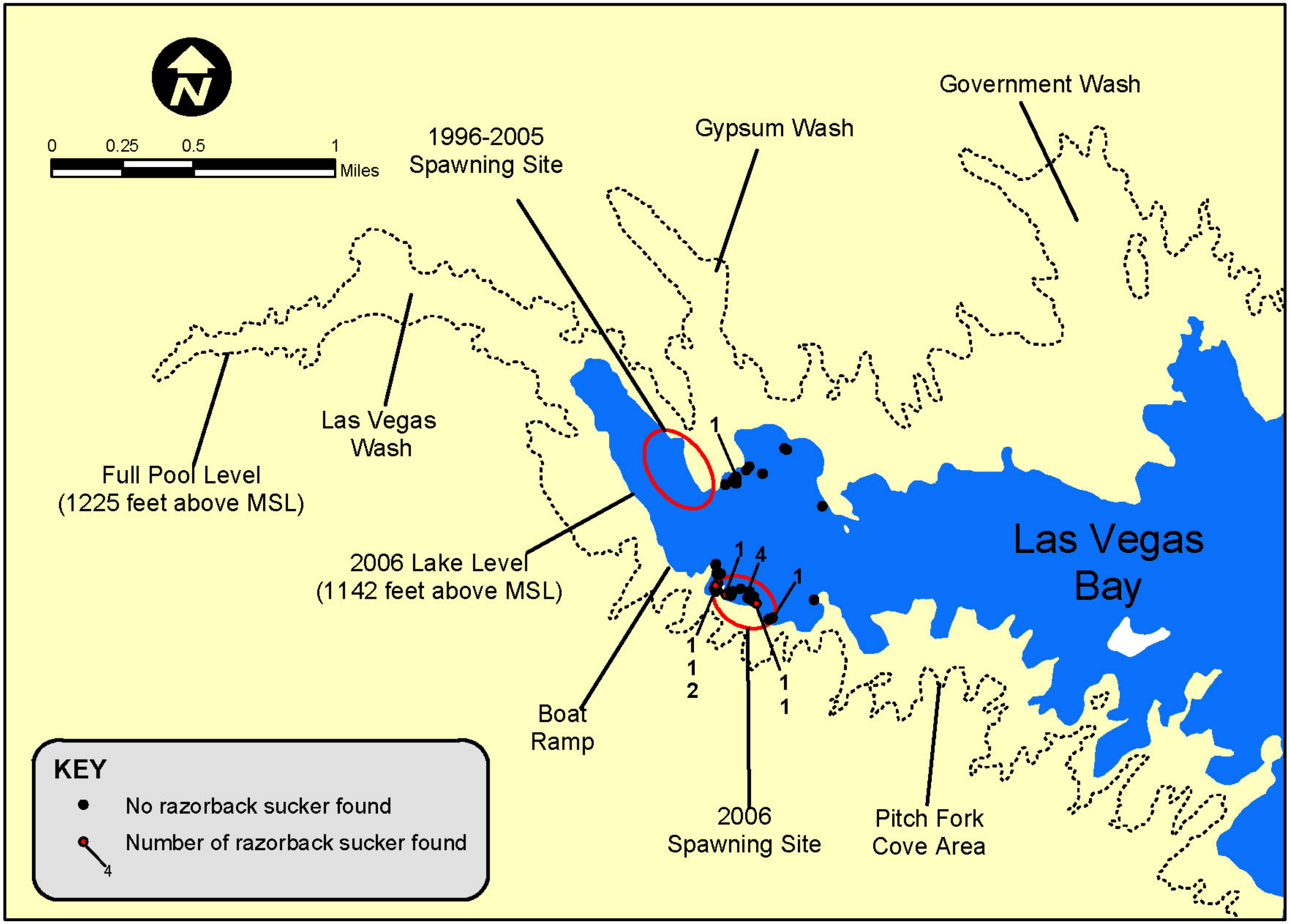

Figure 3. **Las Vegas Bay study area showing locations of trammel netting and numbers of fish captured, July 2005–June 2006.**

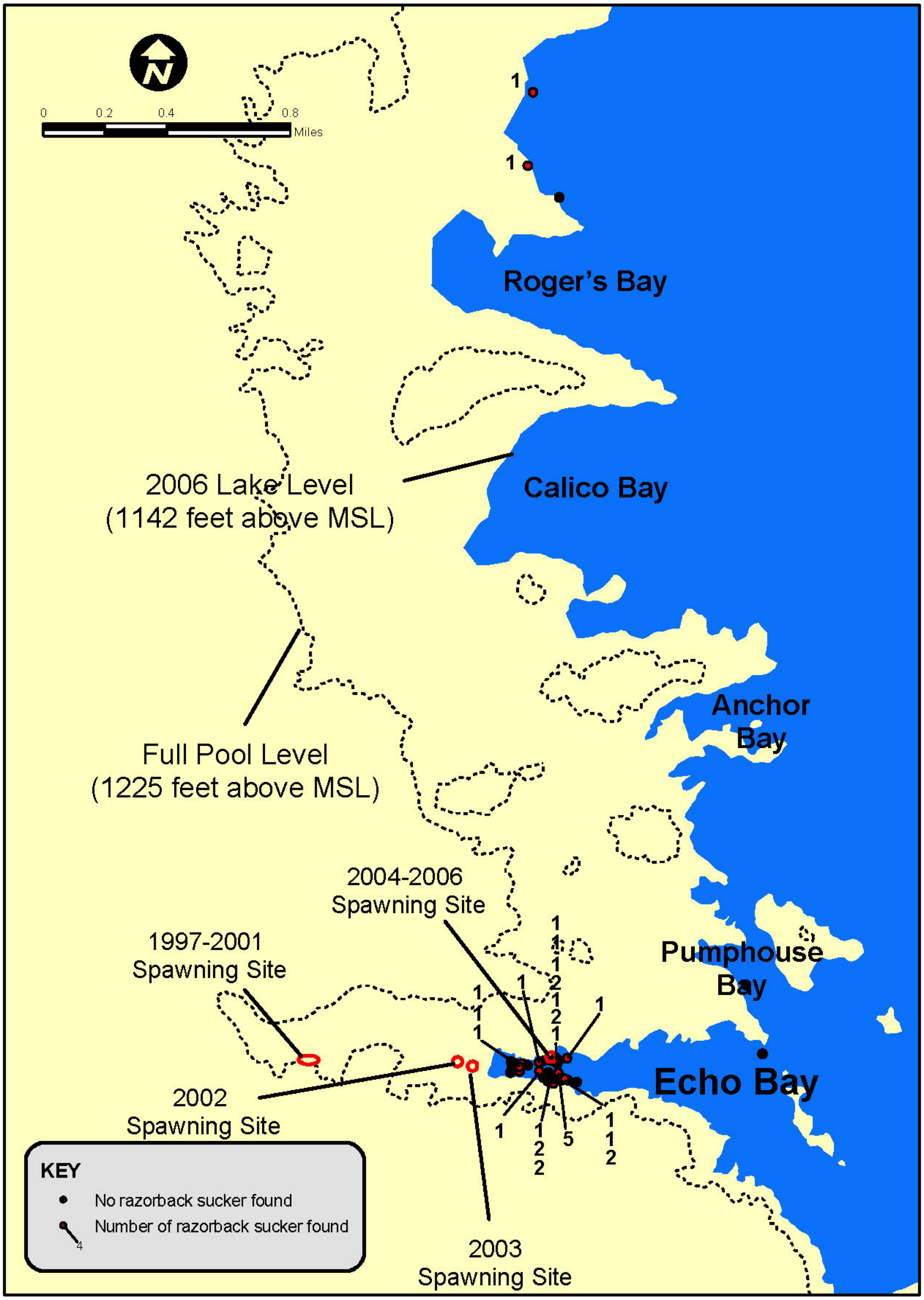

Figure 4. **Echo Bay study area showing locations of trammel netting and numbers of fish captured, July 2005–June 2006.**

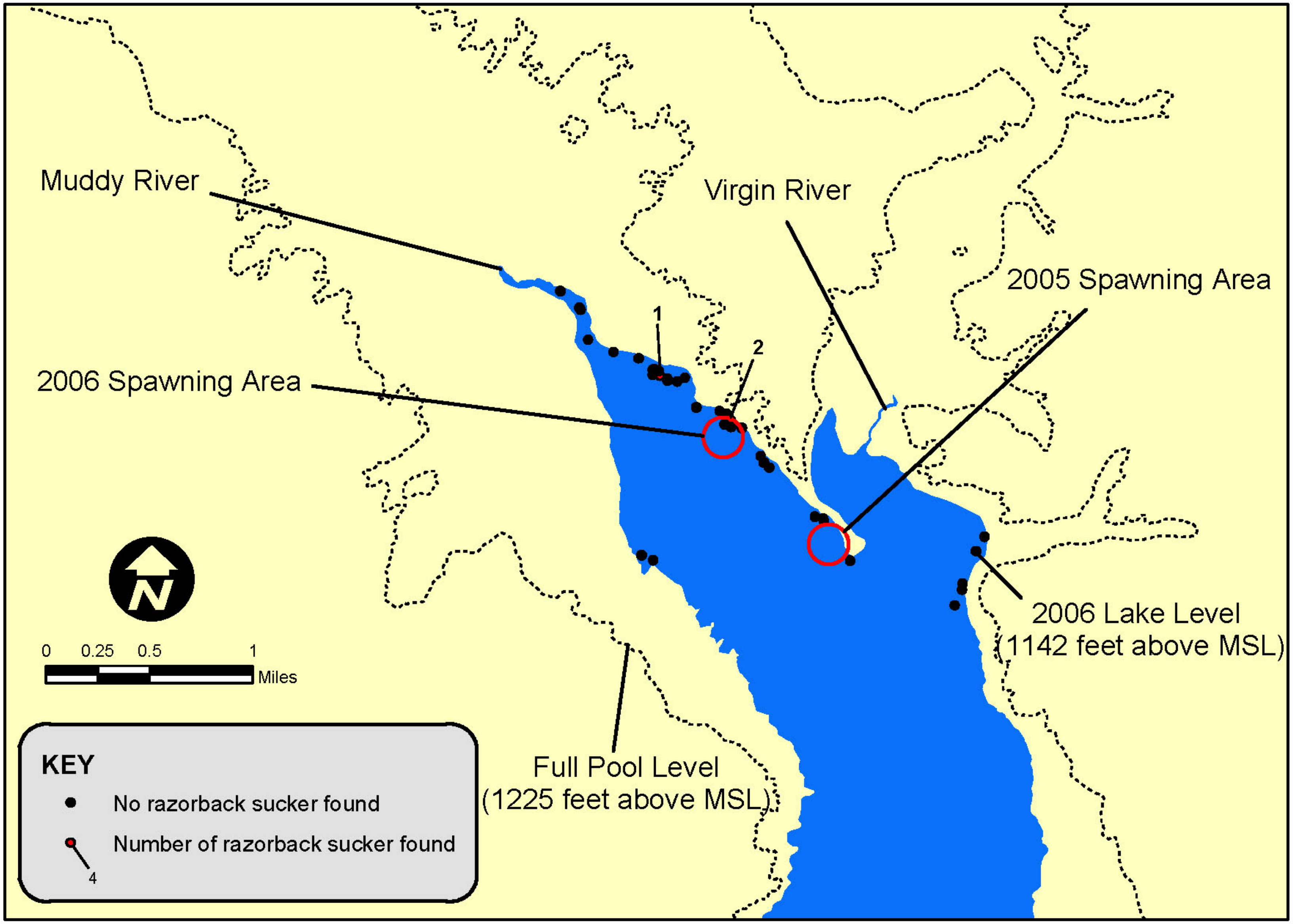

Figure 5. **Muddy River/Virgin River inflow study area showing locations of trammel netting and numbers of fish captured, July2005–June 2006.**

In accordance with the previous six study years (Holden et al. 2000a, 2000b, 2001, Abate et al. 2002, Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005), the timing of trammel netting for the 10th study year was coordinated with seasonal differences in water and air temperature, and the spawning season. Netting during the first two study years revealed that the warmer air and water temperatures encountered during the summer netting efforts appeared to stress razorback sucker that were brought to the surface. For this reason, trammel netting during this year's field season was not conducted during the warm months from June to October. One change implemented during the 2001–2002 field season that was not a part of netting protocol during the previous three field seasons was netting during the razorback sucker spawning season (January–May). This practice was again employed during the 10th study year. Prior to the sixth study year, it was believed that netting during the spawning season was stressful to spawning razorback sucker and that this activity might disrupt spawning or influence adult survival. However, return rates for razorback sucker sampled by the USFWS in 2000 and 2001 were similar to return rates for fish captured outside of the spawning period.

Many of the fish captured by the USFWS were new individuals, indicating that BIO-WEST was not sampling the portion of the populations in both Las Vegas Bay and Echo Bay that moved into these areas late to spawn.

Ten adult and three subadult razorback sucker were captured at Las Vegas Bay (Table 2) during the 44 net nights expended during the 10th study year (Figure 3). Interestingly, most of the captures came from the western shoreline of Las Vegas Bay, providing some evidence of the first spawning location shift for the Las Vegas Bay razorback sucker population since the onset of this 10-year study. In the past, most of the razorback sucker captured in Las Vegas Bay were netted at Blackbird Point (Holden et al. 1997, 1999, 2000a, 2000b, 2001; Abate et al. 2002; Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005). In 2006 the majority of the razorback sucker were captured in shallow water (7–21 ft deep) off a gravelly section of shoreline along the western side of Las Vegas Bay in net sets positioned perpendicular to the shoreline. Initially, efforts were increased along this particular shoreline due to the nearly constant presence of five newly sonic-tagged fish introduced into Las Vegas Bay during the 2005–2006 field season. Later, abundances of larval razorback sucker confirmed this location as the primary spawning area. Only one adult razorback sucker was collected via trammel netting at the tip of Blackbird Point, despite multiple net sets. The razorback sucker catch rate for trammel netting at the Las Vegas Bay area was 0.30 fish/net night for the 10th field season. This rate is higher than the previous year's rate (0.07 fish/net night), and falls well within the upper-end rates reported during the early years of the study (0.10–0.34 fish/net night) (Figure 6).

Throughout Echo Bay nets were set with greater emphasis placed on the back portion of the bay in areas where contacts with sonic-telemetered fish were concentrated, visual observation of adult razorback sucker occurred, larval razorback sucker were found in the highest concentrations, and previous razorback sucker captures had occurred (Figure 4). Razorback sucker were collected from depths ranging from 5–22 feet. In all, 31 adult razorback sucker were captured during 49 net nights (Table 2). The razorback sucker catch rate for trammel

Table 2. Location, tagging, and size information for razorback sucker collected in Lake Mead from July 2005-June 2006.

DATE	CAPTURE LOCATION[a]	STOCKING LOCATION[a]	PIT TAG NUMBER	SONIC CODE	DATE STOCKED	RECAPTURE	TL[b] (mm[f])	FL[c] (mm)	SL[d] (mm)	WT[e] (g[g])	SEX[h]
11/29/05	FDLB	FI	5324641B76	557	11/29/05	n/a	545	503	456	2,290	M
11/29/05	FDLB	FI	5324632D5A	444	11/29/05	n/a	610	561	512	2,700	F
11/29/05	FDLB	FI	53257F4D73	558	11/29/05	n/a	662	612	565	3,500	F
11/29/05	FDLB	EB	53256F4C3C	556	11/29/05	n/a	632	592	540	4,000	F
11/29/05	FDLB	EB	5326000260	447	11/29/05	n/a	635	595	543	4,000	F
11/30/05	FDLB	LVB	5326104578	554	11/30/05	n/a	555	511	475	2,134	M
11/30/05	FDLB	LVB	5326182909	448	11/30/05	n/a	515	480	440	1,940	M
11/30/05	FDLB	LVB	5325661D5B	445	11/30/05	n/a	528	487	452	2,092	M
11/30/05	FDLB	LVB	532575245C	555	11/30/05	n/a	604	553	520	2,528	F
11/30/05	FDLB	LVB	5324051E2D	446	11/30/05	n/a	616	576	535	2,998	F
1/10/06	EB	n/a	1F4A457C56	-	7/25/95	Yes	550	512	-	2,530	M
1/10/06	EB	n/a	53257B6966	-	-	No	630	590	-	3,375	M
1/26/06	LVB	n/a	53256C5E05	-	-	No	740	686	645	4,000	F
2/1/06	EB	n/a	5325515754	-	-	No	705	650	593	4,000	F
2/8/06	EB	n/a	1F4A300F58	-	12/2/03	Yes	631	580	565	3,436	F
2/8/06	EB	n/a	1F4A2B5418	-	12/2/03	Yes	584	541	508	2,558	M
2/8/06	EB	n/a	53257B6966	-	-	Yes	638	593	560	3,278	M
2/9/06	OA	n/a	1F500E4043	-	1/22/02	Yes	638	601	555	-	F
2/10/06	EB	n/a	532624527C	222	12/1/04	Yes	531	488	457	1,896	M
2/10/06	EB	n/a	7F7D2B2D5F	-	4/2/93	Yes	602	556	515	2,750	M
2/10/06	EB	n/a	1F50024946	-	12/2/03	Yes	669	620	574	3,858	F
2/10/06	EB	n/a	1F7B477827	3,344	4/20/97	Yes	614	574	525	2,612	M
2/10/06	EB	n/a	7F7D4C302B	-	2/10/98	Yes	610	570	524	2,502	M
2/16/06	EB	n/a	5324580E11	-	3/17/04	Yes	681	624	585	3,472	F
2/16/06	EB	n/a	53245D0061	-	-	No	601	545	506	3,038	M
2/21/06	LVB	n/a	7F7D140A46	-	3/10/92	Yes	621	580	539	3,300	M
2/22/06	OA	n/a	5324641B76	557	11/29/05	Yes	-	-	-	-	M
2/22/06	OA	n/a	53245E0E7A	-	-	No	687	635	595	4,670	F
2/23/06	EB	n/a	53245D0061	-	2/16/06	Yes	-	-	-	-	M
2/23/06	EB	n/a	2037194749	-	2/25/00	Yes	660	613	568	3,500	F
2/23/06	EB	n/a	1F7B106D69	-	2/24/01	Yes	586	545	505	2,140	M
2/23/06	EB	n/a	2037260E75	-	2/25/00	Yes	640	595	550	3,000	M
3/3/06	EB	n/a	1F4A16047D	-	1/22/02	Yes	611	566	535	3,785	F
3/21/06	EB	n/a	1F78417335	-	2/25/00	Yes	660	635	605	4,395	F
3/21/06	EB	n/a	53255E6C50	-	3/17/04	Yes	606	565	535	3,185	M
3/23/06	LVB	n/a	5325716B62	-	-	No	461	426	385	1,145	UI
3/23/06	LVB	n/a	5326071055	-	-	No	718	662	593	5,065	F
3/28/06	EB	n/a	201D653628	-	3/26/02	Yes	671	629	581	3,230	F

DATE	CAPTURE LOCATION[a]	STOCKING LOCATION[a]	PIT TAG NUMBER	SONIC CODE	DATE STOCKED	RECAPTURE	TL[b] (mm[f])	FL[c] (mm)	SL[d] (mm)	WT[e] (g[g])	SEX[h]
3/29/06	EB	n/a	1F7B106D69	-	2/24/01	Yes	-	-	-	-	M
3/31/06	LVB	n/a	53255E1008	-	-	No	635	580	545	3,030	M
3/31/06	LVB	n/a	5326160B02	-	-	No	605	565	530	2,475	M
3/31/06	LVB	n/a	5326063458	-	3/4/03	Yes	625	575	550	3,230	M
3/31/06	LVB	n/a	53256C6224	-	4/17/03	Yes	687	639	590	4,050	F
4/4/06	LVB	n/a	5326014D46	-	-	No	629	581	527	2,010	F
4/5/06	EB	n/a	1F4A457C56	-	7/25/95	Yes	-	-	-	-	M
4/5/06	EB	n/a	1F7818430E	456	2/24/01	Yes	607	567	488	2,305	M
4/11/06	EB	n/a	53263D264D	355	1/21/03	Yes	608	544	520	2,390	M
4/18/06	EB	n/a	1F7818430E	456	2/24/01	Yes	-	-	-	-	M
4/18/06	EB	n/a	1F7B083727	-	2/25/05	Yes	578	538	506	2,325	M
4/20/06	LVB	n/a	1F4A1C4A31	-	9/30/02	Yes	537	488	428	1,365	M
4/25/06	LVB	n/a	5325776D27	-	-	No	452	420	385	1,145	UI
4/25/06	LVB	n/a	532621056E	-	3/17/04	No	463	425	390	1,215	UI
4/26/06	EB	n/a	53255E6C50	-	3/17/04	Yes	-	-	-	-	M
4/26/06	EB	n/a	1F4A457C56	-	7/25/95	Yes	-	-	-	-	M
4/27/06	OA	n/a	1F4A3C6972	-	1/22/02	Yes	566	520	480	2,185	M
4/27/06	OA	n/a	1F4A2B5418	-	12/1/03	Yes	-	-	-	-	M
5/3/06	LVB	n/a	1F476C5856	--	1/17/01	Yes	580	530	490	2,325	M

[a] Locations: EB = Echo Bay, FLDB = Floyd Lamb State Park, FI = Fish Island, LVB = Las Vegas Bay, OA = Overton Arm (Muddy River/Virgin River inflow area).
[b] TL = Total length.
[c] FL = Fork length.
[d] SL = Standard length.
[e] WT = Weight.
[f] mm = Millimeters.
[g] g = Grams.
[h] Sex: F = female, M = male, UI = sex not determined.

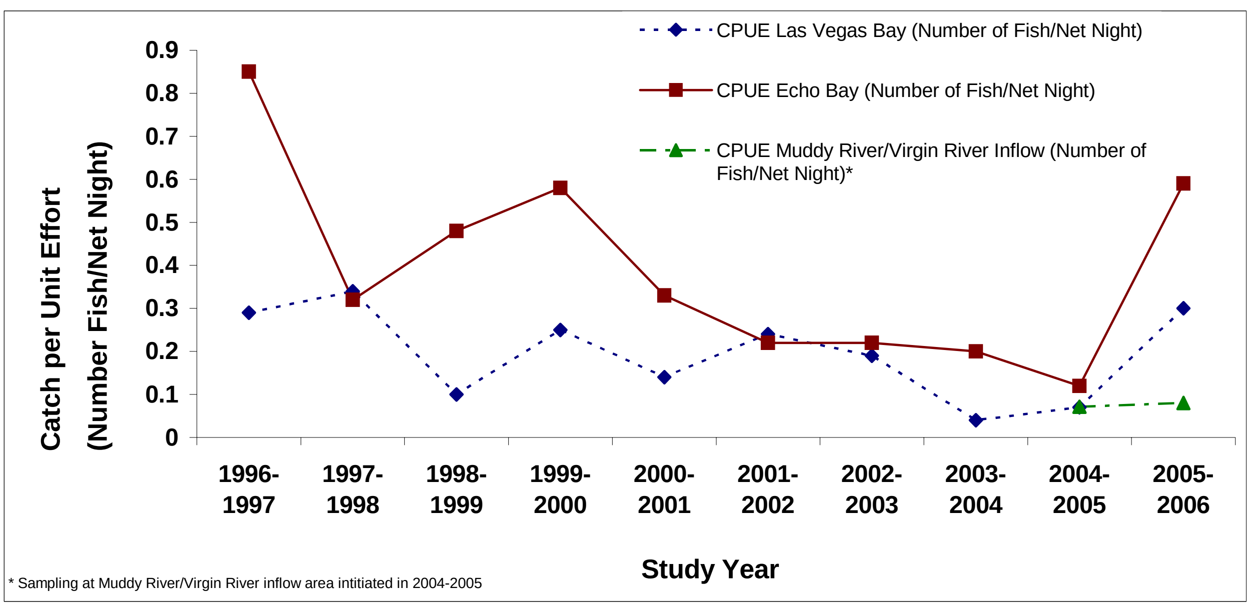

Figure 6. **Trammel netting catch per unit effort (CPUE) during studies on Lake Mead razorback sucker, 1996-2006.**

netting at Echo Bay was 0.59 fish/net night, which is higher than the rate obtained during the previous study year (0.12 fish/net night) (Figure 6). It appears that the increase in CPUE may have been related to the increased number of sonic-telemetered fish at this location, which served to enable more precision of net sets. The overall reduction in the size and topography of Echo Bay during 2005–2006 also likely increased the efficiency of net sets, particularly those sets near the back of Echo Bay, where surface areas were somewhat constrained and we could nearly close off the back portions of the bay with sampling gear.

Razorback sucker were also captured again this season at the Muddy River/Virgin River inflow area (Figure 5). Trammel netting resulted in the capture of three ripe, adult razorback sucker. Depth at capture ranged from 4 to 17 ft. One of the captures was a Floyd Lamb repatriated fish stocked by NDOW in 2002 at Echo Bay (Table 2). The capture location of this fish was near the Muddy River inflow, along the Fish Island shoreline, over cobble- and gravel-sized substrate. This individual razorback sucker recapture marks the first time that a fish stocked into Echo Bay has been captured at the relatively new Fish Island spawning area. Interestingly, this repatriate has never been recaptured at Echo Bay (or elsewhere) since its release in 2002. While this evidence, in combination with sonic telemetry data of a single Floyd Lamb fish migrating from Echo Bay to the Fish Island area, may suggest some degree of interaction between the Echo Bay population and the spawning aggregate at the Muddy River/Virgin River inflow area, we have yet to collect a wild, PIT-tagged fish from Echo Bay at this location. Likewise, we have yet to collect a PIT-tagged individual from the Muddy River/Virgin inflow area at Echo Bay. As more research is conducted in this area of Lake Mead, we hope that such interactions may be better understood.

Another interesting capture from the Muddy River/Virgin River inflow area during the 10th study year was a wild, unmarked, ripe female razorback sucker. This wild fish was collected simultaneously with a third fish, one of the sonic-telemetered fish released during the 2005–2006 study year. Both of these individuals were collected from the same trammel net set, directly off the Fish Island shoreline, near the Muddy River confluence with Lake Mead, over gravel/cobble shoreline habitat (Figure 5 and Table 2). The wild female fish was processed, including PIT tagging, and a fin ray section was obtained for aging purposes (see aging section below). The capture location of these three fish supports the idea that a new population and spawning area exist in Lake Mead (Albrecht and Holden 2005). At minimum, efforts this season continue to demonstrate that razorback sucker spawn outside of the two previously documented spawning locations, a phenomenon unknown until the ninth study year (2004–2005). The razorback sucker catch rate for trammel netting at the Muddy River/Virgin River inflow area was 0.08 fish/net night, similar to last year's catch rate of 0.07 fish/net night (Figure 6).

The first male razorback sucker expressing milt was captured on January 10, 2006, and the first female razorback sucker expressing eggs was captured February 8, 2006; both fish were captured at Echo Bay. Recapture rates varied between study locations in the 10th study year. At Las Vegas Bay, 5 of the 13 razorback sucker caught were recaptures (38.5%); 2 of these were stocked by NDOW, 1 in 2001 and the other in 2002. At Echo Bay, 28 of the 31 razorback sucker caught were recaptures (90.3%). Of the Echo Bay captures, eight had been stocked by NDOW. Of the eight repatriated fish, two were stocked by NDOW in 1995, one from a 2002 stocking, four from 2003, one from 2004, and one from this year's 2005–2006 sonic tagging/stocking event. As indicated above, the some of the fish from both Las Vegas Bay and Echo Bay were recaptured fish originally stocked by NDOW (Table 2), demonstrating that stocked fish are able to find and incorporate themselves into wild populations, a phenomenon also observed by Modde et al. (2005) in the Green River and similarly described in Albrecht and Holden (2005).

In summary, at Echo Bay 93 unique individual razorback sucker were handled during the 10 study years, 71 were captured and PIT-tagged by BIO-WEST personnel, and 22 others were PIT-tagged by NDOW. At Las Vegas Bay, 96 unique razorback sucker were handled, including 81 individuals PIT tagged by BIO-WEST personnel and 15 PIT tagged by NDOW. In addition to last year's two unique captures at the Muddy River/Virgin River inflow area, this year two additional unique razorback sucker were captured, bringing the Fish Island unique razorback sucker total to four individuals (two wild fish from the 2004–2005 study year plus two unique captures from the present study year [1 wild fish and 1 new sonic-tagged fish]). The resulting lake-wide total of unique individual razorback sucker that were handled during this study is 193 individuals.

Video Surveillance

Several attempts were made to observe razorback sucker spawning activity at each of the study areas during spring 2006 using underwater video surveillance. Video surveillance attempts at Las Vegas Bay and the Muddy River/Virgin River inflow area were largely unsuccessful due to elevated water turbidity from inflows and high levels of productivity, which prevented any substantial observations. One notable exception is a single adult razorback sucker visually observed (without the assistance of underwater video equipment) at Las Vegas Bay, along the western shoreline, over a cobble/gravel covered point located some 500 m south of the Las Vegas Wash confluence with Lake Mead (observation occurred on March 22, 2006 during nighttime larval sampling). This sighting, in combination with nearly all of the adult/subadult trammel net captures, abundances of larval fish, and nearly constant use of this location by sonic-telemetered fish, helped to confirm that a new spawning location had been selected by the Las Vegas Bay population.

In contrast, approximately 5 minutes of razorback sucker spawning activity were recorded using underwater video surveillance equipment at Echo Bay on February 6–10, 2006. Video surveillance and direct, visual observation of multiple, spawning razorback sucker (at times more than seven individuals were observed together as a spawning aggregate) indicated the precise location of this season's spawning ground along the northern shoreline of Echo Bay. Direct observations of adult razorback sucker occurred on multiple dates during larval sampling activities at Echo Bay. Echo Bay adult razorback sucker sightings occurred on February 15, March 2, and April 20, 2006, and were all in the same general area. The area was approximately 0.25–0.5 kilometers (km) west of the Echo Bay boat ramp, marina area, and associated infrastructures on the first substantial point west of the houseboat mooring area toward the back of Echo Bay. The spawning area was largely comprised of gravel/cobble substrates and interspersed with regions of loose, conglomerate bedrock formations. Detailed substrate assessments of this location are reported in past annual reports (Welker and Holden 2003, Albrecht and Holden 2005). Razorback sucker were observed spawning in water ranging from shallow shoreline depths of 1–2 feet to nearly 15 feet. Robust numbers of adult razorback sucker captured via trammel netting, abundances of larval fish, and nearly constant use of this location by sonic-telemetered razorback sucker helped confirm this area as a spawning site.

Growth
Thirty-five individual fish were recaptured during the 10th study year, 28 from the Echo Bay area, 5 from the Las Vegas Bay area, and 2 from the Muddy River/Virgin river inflow area. However, annual growth information analyses were only performed using data from 26 of these fish. All 35 recaptures were not included in this analysis; some of the fish were captured more than one time during the 2005–2006 field season, because a full year had not passed between some recapture dates, and some of the recaptures were sonic-tagged fish from 2005–2006 sonic-tagging event described in this report. The difference in total length between capture periods was used to determine mean annual growth (Table 3). The combined, lake-wide, mean annual growth of razorback sucker recaptured from Lake Mead during the 10th study year was 10.6 mm. The combined mean annual growth of recaptured fish the previous study year was 9.5 mm (Albrecht and Holden 2005). Mean annual growth of fish recaptured at Echo Bay was 2.6 mm (3.2 mm for stocked fish and 10.9 mm for wild fish) and ranged from -7.0 mm to nearly 50.0 mm of growth per year. Razorback sucker recaptured at Las Vegas Bay had a mean annual growth of 21.6 mm (41.3 mm for stocked fish and 8.4 mm for wild fish) and ranged from -3.3 mm to 75.4 mm of growth per year. Negative values are thought to reflect measurement error between values recorded during the initial capture occasion and those values observed during the recapture date, and may be a function of very old, slow-growing individuals. Alternatively, this observed change could be reflective of netting-related stress or other unknown, naturally induced stressors (Holden et al. 2000b). In all, and as alluded to in past annual reports, growth rates for Lake Mead razorback sucker continue to be substantially higher than those of other razorback sucker populations, suggesting the overall youthfulness of Lake Mead razorback sucker populations (Modde et al. 1996, Pacey and Marsh 1998, Mueller 2006).

Sonic Telemetry

During the first 9 years of the study, 52 (38 wild and 14 hatchery-reared) fish were equipped with internal or external sonic tags. Approximately half of these tags had a battery life of 12 months (implanted in 1997 and 1998). The other half had a life of 48 months (such as those implanted in 2003 and in 2004). Only one of these tagged fish was active during 2005–2006.

In all cases where sonic-tagged fish moved up and utilized habitats within the riverine portions of Las Vegas Wash, crews took the closest data point accessible by boat. As such, some of the figures below may not fully display movements of sonic-tagged fish up into the shallow, flowing portions of Las Vegas Wash that were inaccessible by boat.

Table 3. Lake Mead recaptured razorback sucker growth histories for fish captured during the 2005-2006 field season.

PIT TAG NUMBER	CAPTURE DATE [a]	TOTAL LENGTH (mm)[b]	RECAPTURE DATE	TOTAL LENGTH (mm)	TOTAL GROWTH (mm)	DAYS BETWEEN MEASUREMENTS	GROWTH PER YEAR (mm/ 365 Days)
LAS VEGAS BAY							
Stocked Fish							
1F4A1C4A31	9/30/2002	269	4/20/2006	537	268	1,298	75.4
1F482B046A	1/17/2001	542	5/3/2006	580	38	1,932	7.2
Mean annual growth of Las Vegas Bay stocked fish							**41.3**
Wild Fish							
7F7D140A46	3/10/1992	548	2/21/2006	621	73	5,096	5.2
5326063458	3/4/2003	635	3/31/2006	625	-10	1,123	-3.3
53256C6224	4/17/2003	618	3/31/2006	687	69	1,079	23.3
Mean annual growth of Las Vegas Bay wild fish							**8.4**
Mean annual growth calculated from Las Vegas Bay stocked and wild fish combined							**21.6**
ECHO BAY							
Stocked Fish							
1F4A457C56	7/25/1995	488	1/10/2006	550	62	3,822	5.9
1F4A2B5418	12/2/2003	580	2/8/2006	584	4	799	1.8
1F4A300F58	12/2/2003	637	2/8/2006	631	-6	799	-2.7
1F50024946	12/2/2003	658	2/10/2006	669	11	801	5.0
532624527C	12/1/2004	524	2/10/2006	531	7	436	5.9
1F4A16047D	1/22/2002	595	3/3/2006	611	16	1,501	3.9
1F4A3C6972 [c]	1/22/2002	554	4/27/2006	566	12	1,556	2.8
Mean annual growth calculated from first and last capture of each stocked fish							**3.2**
Wild Fish							
1F7B477827	4/20/1997	573	2/10/2006	614	41	3,218	4.7
7F7D2B2D5F	4/2/1993	574	2/10/2006	602	28	4,697	2.2
7F7D4C302B	2/10/1998	347	2/10/2006	610	263	2,922	32.9
5324580E11	3/17/2004	666	2/16/2006	681	15	290	18.9
2037194749	2/25/2000	575	2/23/2006	660	85	2,190	14.2
2037260E75	2/25/2000	621	2/23/2006	640	19	2,190	3.2
1F7B106D69	2/24/2001	553	2/23/2006	586	33	1,825	6.6
1F78417335	2/25/2000	704	3/21/2006	660	-44	2,216	-7.2
53255E6C50	3/17/2004	616	3/21/2006	606	-10	734	-5.0
201D653628	3/26/2002	623	3/28/2006	671	48	1,463	12.0
1F7818430E	2/24/2001	577	4/5/2006	607	30	1,866	5.9
53263D264D	1/21/2003	596	4/11/2006	608	12	1,176	3.7
1F7B083727	2/25/2005	521	4/18/2006	521	57	417	49.9
Mean annual growth of Echo Bay wild fish							**10.9**
Mean annual growth Echo Bay stocked and wild fish							**2.6**

OVERTON ARM (MUDDY RIVER/VIRGIN RIVER INFLOW AREA)							
			Stocked Fish				
1F500E4043 [d]	**1/22/2002**	**628**	**2/9/2006**	**638**	**10**	**1,479**	**2.5**
Mean annual growth of Overton Arm stocked fish							**2.5**
Mean annual growth of all Echo Bay, Las Vegas Bay and Overton Arm stocked fish combined							**10.8**
Mean annual growth of all Echo Bay, Las Vegas Bay, and Overton Arm wild fish combined							**10.4**
Mean annual growth of all recaptured fish during course of study year							**10.6**

[a] The date a fish was stocked into Lake Mead.
[b] Total length in millimeters.
[c] Fish collected from Rogers Bay.
[d] Fish stocked originally into Echo Bay.

As highlighted in Welker and Holden (2004), razorback sucker populations in Lake Mead, particularly the Las Vegas Bay population, were subjected to multiple years of low and declining lake elevations. As a result, spawning was not observed at the Blackbird Point spawning area during the 2003–2004 study year, and only four larval razorback sucker were captured during the entire season at Las Vegas Bay, a site that once harbored the largest razorback sucker population in Lake Mead. This drastic decline in larval fish abundance spurred questions pertaining to if/where the Las Vegas Bay population was spawning.

Welker and Holden (2004) proposed experimentally tagging six razorback sucker from Floyd Lamb State Park in hopes that the newly tagged fish would integrate with the wild population in Las Vegas Bay and help to identify new areas where that population was spawning. As a result, during the 2004–2005 study year, six fish were tagged and tracked. All contact was lost with the four fish introduced into Las Vegas Bay within 1 month. It is unknown whether the tags failed or the fish died or left the area. Extensive searches of the lake for the missing fish have been unsuccessful. The two fish (experiencing the same surgery, handling, introduction, and monitoring protocols as the four Las Vegas Bay fish) introduced at Echo Bay integrated with the wild population, and one of the 2004 tags is active to date. This particular fish (code 222) displayed large movement patterns from Echo Bay and within the Overton Arm of Lake Mead and continues to be contacted throughout the Overton Arm. Fish 222 led to the initial observation in 2004 of a new spawning area located at Fish Island near the Muddy River/Virgin River inflow area.

As a result of the likely tag failure in the majority of fish implanted in 2004 (Albrecht and Holden 2005), coupled with projected declines in lake levels during the 2005–2006 study year and the observed integration of hatchery fish with wild razorback sucker populations, 10 additional Floyd Lamb State Park fish were tagged and released in November 2005. Five of these sonic-tagged fish were released into Las Vegas Bay; three were released near Fish Island, and two were released at Echo Bay. In general, telemetry efforts were more successful during the past field season, with 9 of the 10 sonic telemetered fish being contacted on a regular basis, even to the time of this writing. It is hypothesized that newly redesigned tags and the associated improved manufacturing process increased the longevity, consistency, and durability of implanted tags during the 2005–2006 study year. Of the 10 individuals released, only a single Echo Bay fish was lost, likely a result of tag malfunction. Repeated attempts (lake-wide sonic surveys) were unsuccessful in relocating this particular individual, while the remaining fish continue to be contacted within the vicinity of their respective points of release. The following dialog describes the history and habitat use of the 10 individual razorback sucker implanted during 2005–2006 and the movements of the single, residual fish (code 222) from the 2004–2005 sonic implantations.

Las Vegas Bay

Fish 445

On November 30, 2005, sonic tag 445 (48-month battery life) was implanted into a 528 mm TL male captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. Fish 445 was stocked into Las Vegas Bay near Gypsum Wash the same day that tagging occurred. This fish (and all newly tagged and stocked fish) was monitored for 48 hours after stocking and contacted multiple times from the point of release. This fish remained relatively sedentary for several days immediately following release, moved near Black Bird Point, and was later contacted in the flowing portions of Las Vegas Wash on December 7, 2005. The fish was then contacted almost weekly through May along the western shoreline of Las Vegas Bay. Fish 445 was contacted more than 30 times, all within the Las Vegas Bay vicinity. Average depth utilized by this fish during the spawning period (December through May) was 23 ft and ranged from 4 to 47 ft. The affinity of this fish for the western shoreline of Las Vegas Bay lead researchers to investigate this area of the bay for possible spawning activity, resulting in the capture of all but one adult via trammel netting, as well as the bulk of larval production observed during the 2006 spawning period. Habitat use of this fish (and the other four tagged fish in Las Vegas Bay), coupled with netting and larval results, helped to define the first documented shift in spawning location in this area of Lake Mead. Fish 445 is still active and was last contacted in June 2006 near the mouth of Las Vegas Bay (for the purposes of this report) and it is anticipated that continued movement and tracking of this fish will occur throughout the summer months and during the next field season (Figure 7).

Fish 446

On November 30, 2005, sonic tag 446 (48-month battery life) was implanted into a 616 mm TL female captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. Fish 446 was stocked into Las Vegas Bay near Gypsum Wash the same day that tagging occurred. As with all stocked fish, fish 446 was monitored for 48 hours after stocking. This fish remained near its release point for several days and then moved to the northern shoreline of Las Vegas Bay near Black Bird Point and was later contacted in the inflow region of Las Vegas Wash on December 5, 2005. On December 16, 2005, fish 446 was contacted along the western shoreline of Las Vegas Bay, where it was found regularly throughout the rest of the spawning season. This fish did make one trip up into the flowing portion of Las Vegas Wash, thereafter returning to the western shoreline of Las Vegas Bay.

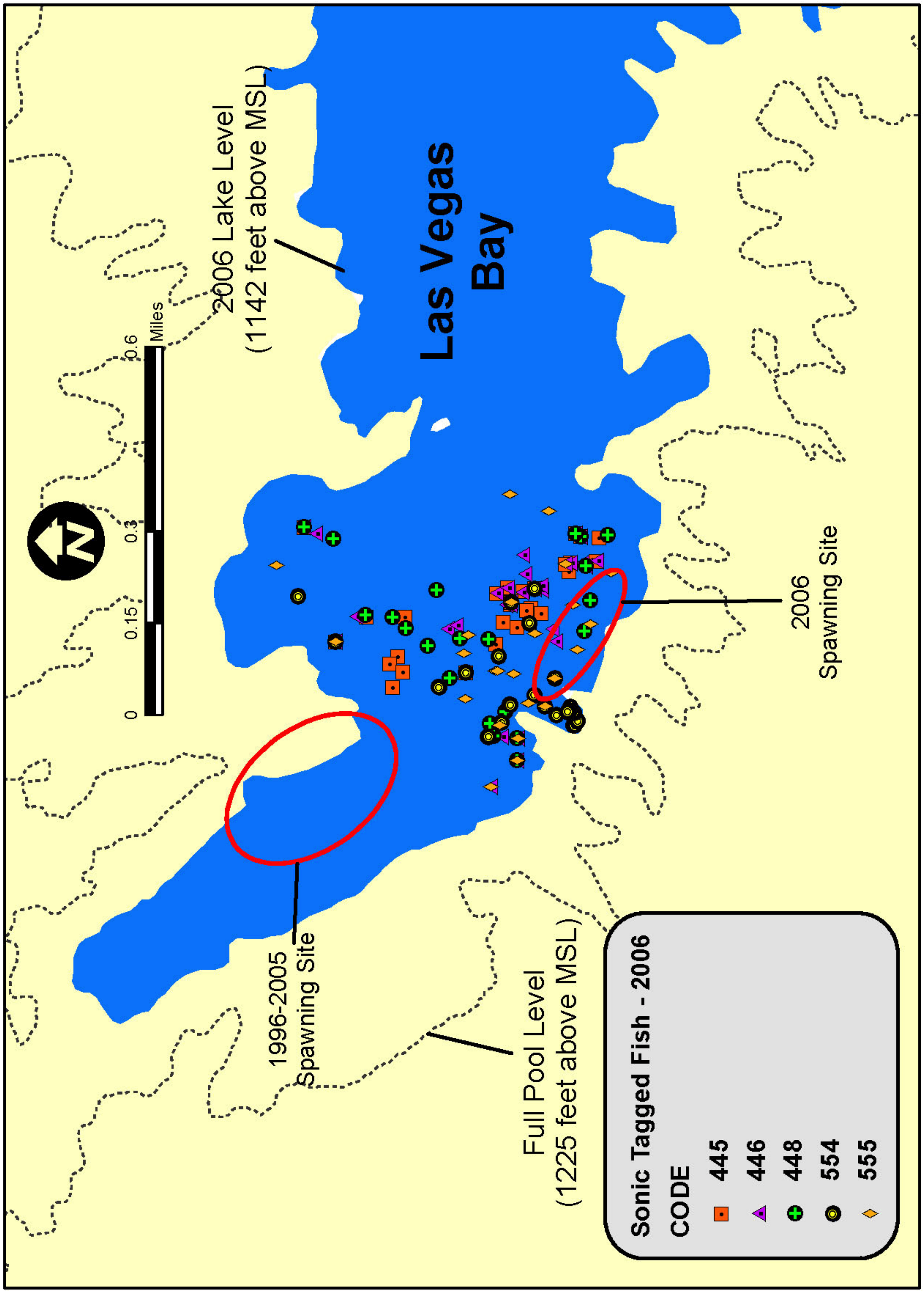

Figure 7. **Distribution of sonic-tagged fish numbers 445, 446, 448, 554, and 555 in Las Vegas Bay during 2005–2006.**

Fish 446 was contacted more than 31 times, with all contacts occurring within the Las Vegas Bay vicinity and most of the contacts occurring near the western shoreline of Las Vegas Bay. Average depth utilized by this fish during the spawning period (December through May) was 24 ft and ranged from 3 to 44 ft. Fish 446 displayed definite affinity for the western shoreline of Las Vegas Bay, increasing the evidence of a shift in spawning location for the Las Vegas Bay razorback sucker population. Fish 446 remained active and was last contacted in June 2006 near the mouth of Las Vegas Bay. It is anticipated that continued movement and tracking of this fish will occur throughout the summer and during the next field season (Figure 7).

Fish 448

As with the tagged fish mentioned previously, fish 448 was tagged November 30, 2005. Tag 448 (48-month battery life) was implanted into a 515 mm TL male razorback sucker captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. Fish 448 was also stocked into Las Vegas Bay near Gypsum Wash the same day that tagging occurred. This fish remained near its release point for several days and then moved near the mouth of Las Vegas Wash on December 7, 2005. Fish 448 displayed a rather strong affinity for Las Vegas Wash and the western shoreline of Las Vegas Bay, where it was contacted on multiple occasions through April 24, 2006. Since April, fish 448 has most often frequented the deeper areas near the mouth of Las Vegas Bay. In all, fish 448 was contacted on more than 30 occasions, with all contacts occurring within the Las Vegas Bay vicinity and most of the contacts occurring near the western shoreline of Las Vegas Bay or in the shallow, flowing portions of the western side of Las Vegas Wash. Interestingly, this fish did display diel migrations from the flowing portions of the wash (day) to the western shoreline of Las Vegas Bay (night) throughout the spawning period, presumptively indicating directed movement toward spawning areas during nighttime hours. Typically, fish 448 would follow contours along the western shoreline of the Las Vegas Wash into Las Vegas Bay (unfortunately much of this information is not portrayed in the maps provided due to inaccessibility of Las Vegas Wash by boat). Average depth utilized by this fish during the spawning period (December through May) was 14 ft and ranged from less than 3 to over 29 ft. Fish 448 displayed an affinity for the gravel/cobble sections of the western shoreline of Las Vegas Bay, further supporting a shift in spawning location of the Las Vegas Bay razorback sucker population. Fish 448 remained active and was last contacted in June 2006 near the mouth of Las Vegas Bay. It is anticipated that continued movement and tracking of this fish will occur throughout the summer months and that tracking will enable habitat utilization assessments throughout the next field season (Figure 7).

Fish 554

Fish 554 was stocked into Las Vegas Bay near Gypsum Wash, tagged on November 30, 2005, and implanted with a 48-month battery life sonic tag. Tag 554 was implanted into a 555 mm TL male razorback sucker captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. This fish was monitored for 48 hours after stocking and remained near the initial release point for several days. Fish 554 was then contacted on December 7, 2005, near the mouth of Las Vegas Wash. This fish also made trips up the flowing portions of Las Vegas Wash but displayed a strong affinity for a small cove located on the western shoreline of Las Vegas Bay, approximately 200 m south of the Las Vegas

Wash inflow. This cove contained areas of bedrock material, as well as sections of gravel and cobble substrates. It was at this particular location in Las Vegas Bay where the highest larval densities were observed during the 2006 spawning season. Fish 554 was contacted on over 24 instances during the 2005–2006 field season. Mean depth at point of contact was nearly 15 ft and ranged from less than 3 ft to more than 38 ft. Contact with fish 554 continued through June and is expected in 2006–2007 (Figure 7).

Fish 555

This 604 mm TL female razorback sucker (captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS) was stocked into Las Vegas Bay near Gypsum Wash, tagged on November 30, 2005, and implanted with a 48-month battery life sonic tag. This fish was also monitored for 48 hours after stocking and remained near the initial release point for several days. Fish 555 was then contacted on December 7, 2005, near the entrance of Las Vegas Bay. On December 16, 2005, fish 555 moved near the western shoreline of Las Vegas Bay, where it remained in the general vicinity through April 12, 2006. On this date the fish moved into the flowing portions of Las Vegas Wash. Later, on April 19, 2006, this fish was again found along the western shoreline of Las Vegas Bay; it remained in the general vicinity until June 2006. Last contact with fish 555 was in the center of Las Vegas Bay, near the navigational buoys and water quality monitoring structure at the mouth of Las Vegas Bay. During the spawning period (December through May), average depth at point of contact was nearly 17 ft and ranged from less than 3 to more than 31 ft. In all, fish 555 was contacted on more than 24 occasions. We anticipate that further monitoring of this fish will provide valuable habitat utilization information throughout the next field season and beyond (Figure 7).

Echo Bay Area

Fish 447

On November 29, 2005, sonic tag 447 (48-month battery life) was implanted into a 635 mm TL female that was captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. Fish 447 was contacted over 40 times during the 2005–2006 study year. Upon release fish 447 remained in the back of Echo Bay through January 10, 2006, typically frequenting the shoreline areas and inundated vegetation near the mouth of Echo Bay Wash. On January 11, 2006, fish 447 was contacted near the mouth of Pumphouse Bay, the next cove north of Echo Bay. Fish 447 then began to display a unique diel migration pattern: fish 447 was typically located within/near Pumphouse Bay during the day and then found at the back of Echo Bay during crepuscular/nighttime hours. When in Echo Bay, fish 447 was typically found near the first point towards the back of Echo Bay from the Echo Bay Marina Structures along the northern shoreline. This point was the same location described in Albrecht and Holden (2005), where the bulk of the 2005 spawning activity in Echo Bay occurred. The continued presence of fish 447 and the affinity of fish 222 (see Overton Arm sonic telemetry section below) for this particular point, coupled with adult netting and larval captures indicated that this same location was used by the Echo Bay razorback sucker population for spawning in 2006. Later, visual observations and underwater filming helped to confirm this location. On

March 21, 2006, fish 447 made a single trip to Rogers Bay. This is a fairly familiar trend for Echo Bay-associated fish; migrations to and from Echo to Rogers Bay were common throughout the course of our investigations (see Welker and Holden 2003, 2004; Albrecht and Holden 2005). The week after being found in Rogers Bay, fish 447 was again located at the back of Echo Bay. Since that time, fish 447 has been contacted regularly at the back of Echo Bay or between Echo and Pumphouse bays. Mean depth utilized by fish 447 during the spawning period (December through May) was nearly 20 ft and ranged from less than 2 ft to more than 78 ft. Fish 447 remains active (Figure 8).

Fish 556

Fish 556, one of two sonic-tagged fish released into Echo Bay during the 2005–2006 field season, was implanted November 29, 2005, with sonic-tag code 556 (48-month battery life). This fish was a 632 mm TL female captured at Floyd Lamb State Park during the collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. Fish 556 was stocked into Echo Bay the same day that tagging occurred in conjunction with fish 447. Both fish experienced identical surgical, transportation, and handling protocols, and were implanted with the same tag type as all fish implanted during 2005–2006. During the first 24 hours after its release, fish 556 was found near its original stocking site at the back of Echo Bay. Twenty-four hours later, fish 556 was contacted near the entrance of Echo Bay, just north of the Bighorn Islands in 35 ft of water. Unfortunately, this was the last contact made with fish 556. Given that multiple, lake-wide searches for this fish failed to re-establish contact, it seems most probable that tag failure occurred. Tag failure would explain the lack of contact with fish 556, particularly given the relatively high rate of success displayed by 9 of the 10 fish tagged this season. As such, we feel relatively confident that if the fish had perished, or had simply shed its tag, we would have been able to continue to hear the tag and ultimately retrieve it. Despite the lack of contact with this individual, we will continue to search for the fish throughout the summer and into next field season (Figure 8).

Muddy River/Virgin River Inflow Area

Fish 444

This 610 mm TL female razorback sucker (captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS) was stocked into the Overton Arm at Fish Island, a relatively new spawning area found in 2005, located between the inflow areas of the Muddy River and Virgin River. Fish 444 was one of three fish released at this location in an effort to further investigate razorback sucker habitat use patterns in this area of Lake Mead. Fish 444 was implanted with a sonic tag (with a 48-month battery life) on November 29, 2005. During the 48-hour post-stocking period, fish 444 remained near the initial release point for 24 hours, after which it was contacted along the western shoreline of the Overton Arm, approximately 2 km south of the Overton Marina. Fish 444 was then contacted on December 7, 2005, north of the Overton Marina on the western shoreline. From December 13, 2005, fish 444 could be consistently found using habitats near the inflow of the Muddy River at/near a particular deep, submerged channel region formed by the Muddy River but located within the lentic portions of Lake Mead. Fish 444 remained at/near the submerged channel in the

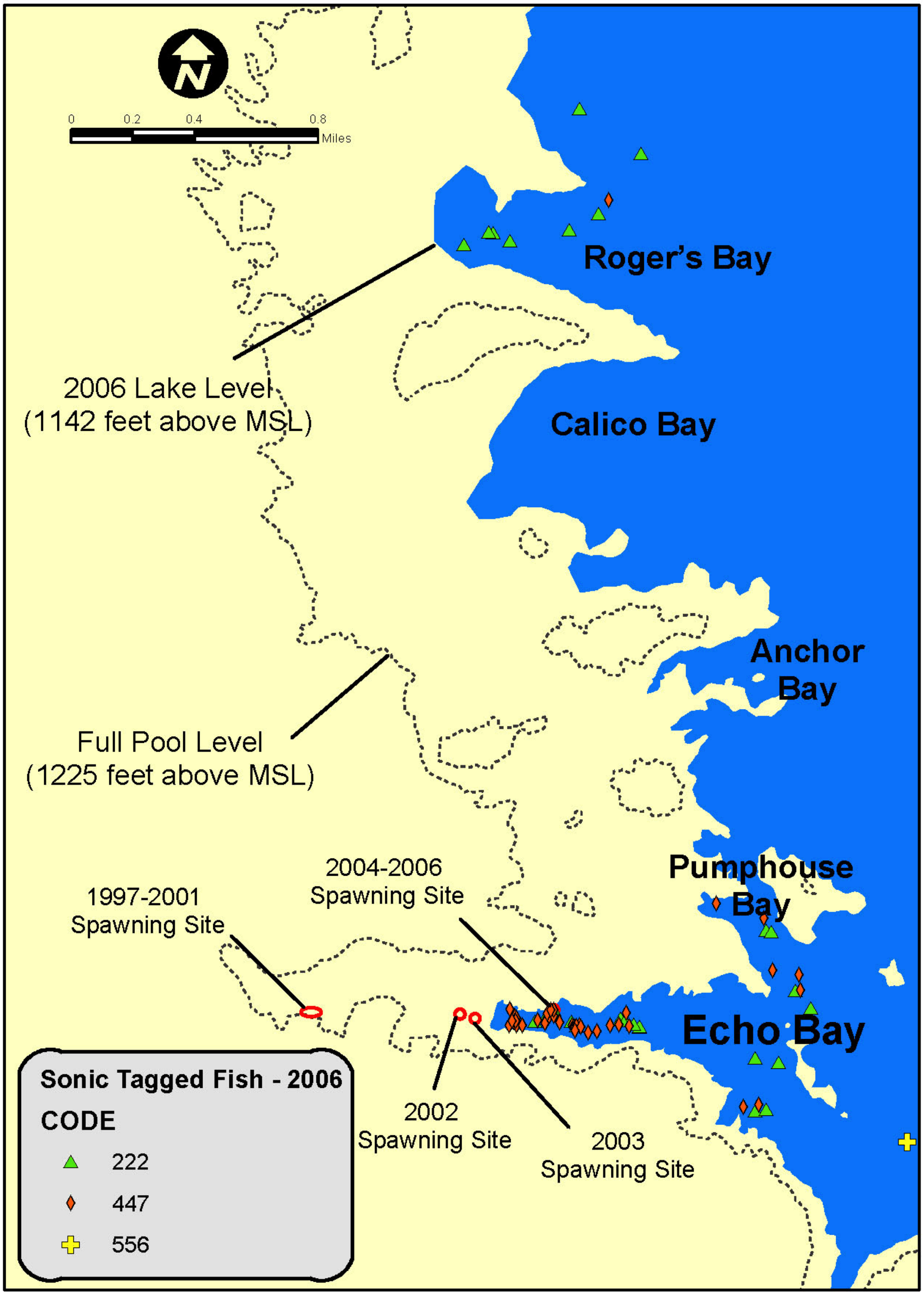

Figure 8. **Distribution of sonic-tagged fish numbers 447, 556 and 222 in the Echo Bay area during 2005–2006.**

northern end of the Overton Arm through December 21, 2005. Throughout this same time frame, fish 444 could also be found along the Fish Island shoreline over gravel/cobble substrates, approximately 1–2 km north of the 2005 spawning area identified by Albrecht and Holden (2005). On January 4, 2006, the fish 444 moved up into the flowing portions of the Muddy River proper, some 300 m from the confluence of the Muddy River with Lake Mead. Fish 444 was found the next day at the Muddy River/Lake Mead interface area and along the Fish Island shoreline area. This pattern of habitat use continued into April 2006. Interestingly, fish 444 was contacted on one occasion nearly 1–2 km up the Muddy River proper, which at the time was accessible by boat. A similar riverine-like habitat affinity was observed in association with sonic-tagged fish using the flowing portions of Las Vegas Wash (Holden et al. 1997, Holden et al. 1999, Holden et al. 2000a, Holden et al. 2000b, Holden et al. 2001, Abate et al. 2002, Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005). Toward mid-April, 2006, fish 444 moved into deeper water north of the Overton Marina, where it was last contacted. During the spawning period (December through May), average depth at point of contact was approximately 15 ft, and contact depths ranged from less than 5 ft to more than 25 ft. Fish 444 was contacted more than 24 times. We expect continued contact with fish 444 during the 2006–2007 season (Figure 9).

Fish 557

On November 29, 2005, sonic tag 557 (48-month battery life) was implanted into a 545 mm TL male that was captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. Fish 557 was contacted over 21 times during the 2005–2006 study year. Fish 557 remained at/near its original Fish Island release point through December 7, 2005. On December 8, 2005, fish 557 was contacted near the Muddy River inflow area in a dense stand of inundated vegetation. It remained in the general vicinity until December 28, 2005. Fish 557 was then contacted fairly consistently using habitats along the Fish Island shoreline and near the Virgin River inflow region. Fish 557 continued to be contacted at/near Fish Island or the Muddy River/Virgin River inflow area through February 21, 2006. On February 22, 2006, fish 557 was recaptured in a trammel net set along the northernmost reaches of the Fish Island shoreline. Fish 557 was collected along with a new, unmarked, ripe, wild, female razorback sucker in the same net. Both fish were ripe and were collected over an area of gravel/cobble substrate presumptively at this season's spawning area (later larval fish presence confirmed successful spawning at this location; see larval section). On March 15, 2006, fish 557 was recontacted to the south of the Virgin River inflow area along the eastern shoreline of the Overton Arm. Fish 557 returned to the Fish Island shoreline area April 12, 2006, and has consistently been found near the middle of the northern portions of the Overton Arm since then. Contacts with fish 557 have typically been made between the Virgin River inflow and the Overton Marina area. Mean depth utilized by fish 557 during the spawning period (December through May) was nearly 17 ft and ranged in depth from less than 4 ft to more than 26 ft. Fish 557 continues to remain active and utilizing habitats within the Overton Arm (Figure 9).

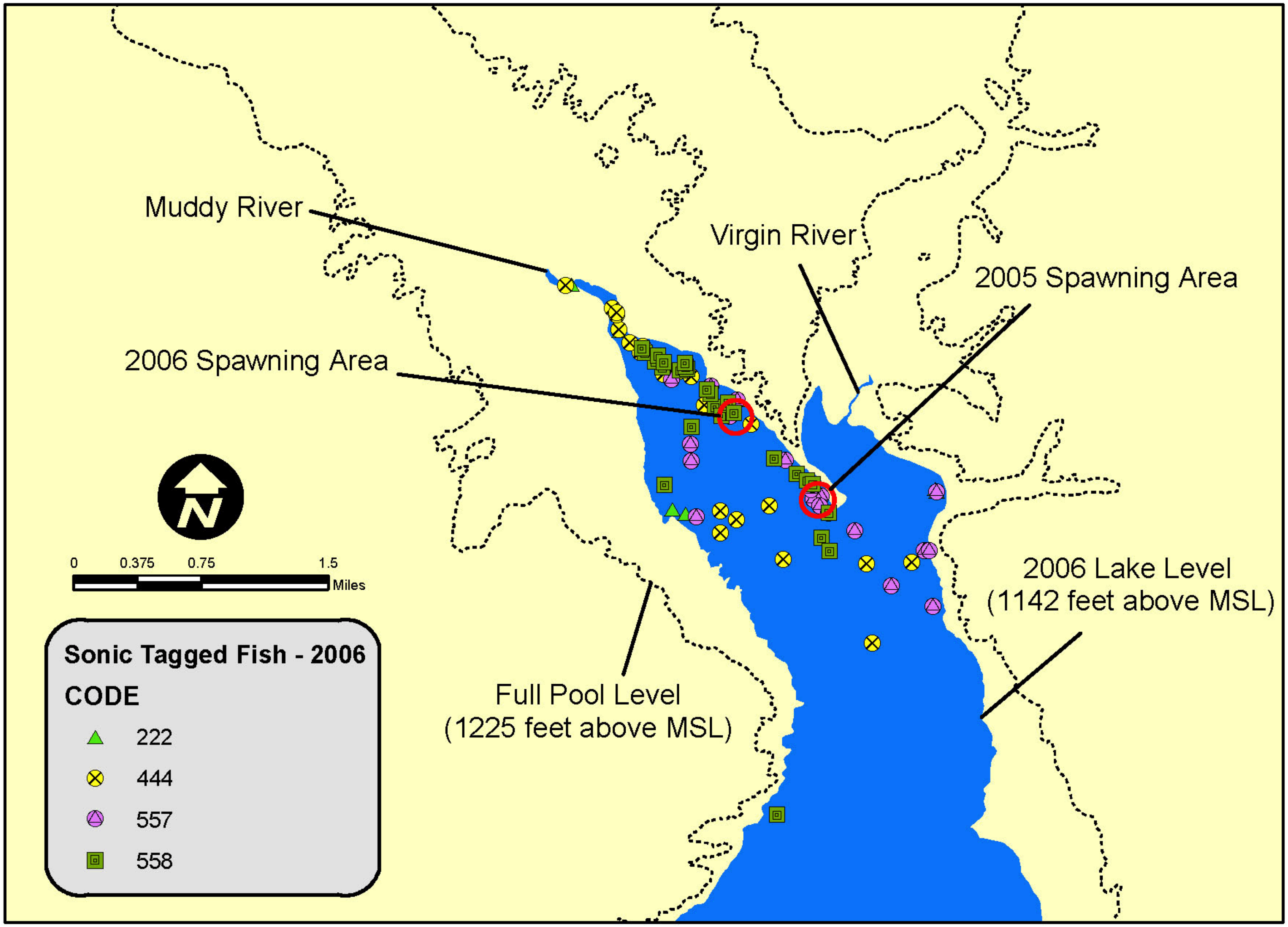

Figure 9. **Distribution of sonic-tagged fish numbers: 444, 557, 558, and 222 in the Overton Arm vicinity during 2005–2006.**

Fish 558

Fish 558 was also stocked into the Overton Arm area, along with sonic-tagged fish 557 and 444. Fish 558 was tagged on November 30, 2005, and implanted with a 48-month battery life sonic tag. Tag 558 was implanted into a 662 mm TL female razorback sucker captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST, NDOW, and the USFWS. This fish was monitored for 48 hours after stocking and remained near the initial release point for several days. Similar to fish 557, fish 558 was contacted on December 7, 2005, near the Muddy River inflow area. It remained in the vicinity through approximately January 4, 2006. Contacts with fish 558 between January and mid-March tended to alternate between the Muddy River inflow area and along the Fish Island shoreline. After mid-March fish 558 was found near the Virgin River inflow or generally within the open water habitats north of the Overton Marina. Contacts were associated with the presence of the other three tagged razorback sucker (codes 222, 444, 557) frequenting the Overton Arm. Fish 558 was contacted more than 27 times during the 2005–2006 field season. Mean depth at point of contact was approximately 16 ft, with contact depths ranging from less than 7 to more than 42 ft. To date, sonic telemetered fish 558 remained active and could be found within the Overton Arm (Figure 9).

Fish 222

As discussed in Albrecht and Holden (2005), perhaps the most interesting razorback sucker movement patterns documented during the 2004–2005 study year were those of sonic-tagged fish 222. On December 1, 2004, sonic tag 222 (48-month battery life) was implanted into a 524 mm TL male captured at Floyd Lamb State Park during collaborative adult trammel netting by BIO-WEST and NDOW. Fish 222 was stocked into Echo Bay on the same day that tagging occurred. This fish was monitored for 48 hours after stocking. Upon introduction to Lake Mead, fish 222 stayed within approximately 50–100 m of its initial release site, near the Echo Bay launch ramp, for the first 2 days. This fish then left Echo Bay and was not contacted until January 7, 2005, when it was located between the Overton Marina and the Muddy River inflow area, during a lake-wide tracking effort, some 15 miles north of its release site. Fish 222 was then contacted six times over a period of approximately 1 month (through January and into February) in gravel bars and newly inundated vegetation shoreline habitats with highly turbid waters near the inflows of the Virgin and Muddy rivers. Contacts were often made near the shorelines of Fish Island. Because of the consistent contact made with this fish in an area of the lake that appeared to possess the physical characteristics previously documented to be preferred by spawning razorback sucker populations elsewhere in Lake Mead, BIO-WEST personnel initiated trammel netting to test the hypothesis that fish 222 had successfully integrated with wild razorback sucker and initiated spawning activities with a wild spawning aggregate. The first night of netting near fish 222's location produced a single ripe, male razorback sucker that had never before been captured. Subsequent netting in 2005 produced a single, wild, female razorback sucker. Later, location data from tagged fish 222 were used to establish larval razorback sucker sampling locations, resulting in larval captures in both Echo Bay and near Fish Island during both the 2004–2005 and 2005–2006 study years. On March, 15, 2005, fish 222 moved back to Echo Bay from the Muddy River/Virgin River inflow area and was then contacted near a high-quality gravel bar below a cliff area on the north side of Echo Bay. Contact with fish 222 was made in mid-March in Pumphouse Bay, north of Echo Bay. The contact suggested that fish 222 was located in a dense stand of recently submerged vegetation, a behavior typical of post-spawn razorback sucker (Mueller et al. 2000). Fish 222 was then contacted in Rogers Bay in late June 2005. Location of fish 222 was in surprisingly shallow water (less than 20 ft) near the back of Rogers Bay, an area within 100 m of the shoreline.

During late summer 2005, fish 222 was contacted on a nearly monthly basis. From July to September 2005, fish 222 remained within the Rogers Bay vicinity, often frequenting the westernmost and northern shorelines. Typically, contacts were at depths of 30–50 ft. On November 2, 2005, sonic-telemetered fish 222 was followed from the Slim Creek/Black Ridge area of the Overton Arm nearly to the Overton Marina. Fish 222 was found to be capable of navigating this distance in a little over 2.5 hours while following the 25–50 ft depth contour along the western shoreline of the Overton Arm. At times the fish covered 500–600 m during a 20-minute period of continuous sonic tracking. Extrapolating this swimming speed, it appears generally feasible for a razorback sucker starting from Echo Bay to reach the northernmost portions of the Overton Arm well within the confines of a single day. Since fish 222 appears to have integrated with other, wild razorback sucker, it seems likely that there is at least some nominal degree of intermixing between fishes that spawn at Echo Bay and those that spawn at/near the Muddy River/Virgin River inflow area. This notion is further exemplified by the movements and behavior of fish 222 during the course of the 2006 spawning season (December–May).

For example, on December 1, 2005, fish 222 was found to have returned to Rogers Bay where it remained until December 8, 2005. On this date fish 222 was located near the back of Pumphouse Bay. Contacts later that day placed fish 222 within the confines of Echo Bay. Fish 222 remained within the Echo Bay/Pumphouse Bay vicinity through December 28, 2005, with daily migrations to/from the back of Echo Bay (night/crepuscular hours) and Pumphouse Bay (daylight hours), typically accompanied by fish 447. On January 4, 2006, fish 222 was located within the flowing portions of the Muddy River, where it was contacted through January 5, 2006. Five days later, on January 10, 2006, sonic-tagged fish 222 returned again to Echo Bay, where it remained at or near the 2006 presumptive spawning location until February 16, 2006, again displaying the diel spawning movements previously described. In fact, fish 222 was captured via trammel netting on February 10, 2006, in a net set near the presumptive 2006 Echo Bay spawning area. Fish 222 was longer (7 mm TL) and heavier (202 g) than it was when it was subjected to surgical implantation methodologies and introduced into Echo Bay in 2004. Movements of sonic-tagged fish 222 and 447 in Echo Bay allowed for precise placement of both adult trammel netting and larval collection sites. Fish 222 was later found in the Overton Arm along the Fish Island shoreline on February 21, 2006, with fish 557, which was collected in a trammel net along with a wild female razorback sucker at/over the 2006 presumptive Fish Island spawning site on February 22, 2006. Fish 222 evaded trammel net sets on this occasion; fish 557 was not measured to avoid stress. Several subsequent contacts were made with fish 222 near the Muddy River/Fish Island shoreline until March 16, 2006, at which time fish 222 returned yet again to Rogers Bay. On March 21, 2006, 1 week after being contacted in Rogers Bay, fish 222 was found a substantial distance (approximately 1–2 km) up the Muddy River proper. Fish 222 remained in the Muddy River/Virgin River inflow region until April 20, 2006, where it was contacted until the first week of May 2006 when it was located at Rogers Bay. Overall, during the course of the 2005–2006 study year, fish 222 occupied a mean depth of approximately 29 ft, with contact depths ranging from less than 4 ft to more than 78 ft. Lastly, fish 222 was contacted on over 40 occasions during the 2005–2006 study year and was found to be utilizing spawning areas at both Echo Bay and the Muddy River/Virgin River inflow area (Figures 8, 9). Fish 222 remains at Rogers Bay, and it is our hope that continued contact throughout the summer months will facilitate yet another year of habitat research.

Telemetry Summary

During the 10th study year, habitat use and movements of 11 sonic-tagged fish were monitored. One of the fish was a residual tagged fish (code 222) from the 2004 tagging event, while the others were tagged this season. The fish implanted in 2004 continued to display an extensive utilization of habitats throughout the Overton Arm with contacts stemming from Echo Bay to the Muddy River, which is the broadest habitat utilization by a tagged razorback sucker that we have seen in this part of Lake Mead to date. Interestingly, fish 222 likely participated in spawning at both the 2006 Fish Island spawning site and the Echo Bay spawning site. The other 10 fish served to retest an experiment proposed by Welker and Holden (2004) to utilize hatchery-reared Floyd Lamb State Park razorback sucker, equip them with sonic tags, and use telemetry to locate wild spawning razorback sucker aggregates. Five of the newly tagged fish were stocked into Las Vegas Bay and served to evaluate the effects of projected declining lake levels during the 2005–2006 field season and identify whether the Las Vegas Bay population began spawning outside of their historic Blackbird Point area. Much information was gained by following the five newly tagged individuals in Las Vegas Bay and, in association with declining lake levels and the inundation of Blackbird Point with sediment from Las Vegas Wash, spawning was documented to occur in a new location within Las Vegas Bay for the first time during this 10-year study.

At Echo Bay, where 2 of the 10 newly tagged fish were introduced, contact with one of the sonic-tagged fish was lost within 48 hours. However, movement patterns of the other sonic-telemetered fish in Echo Bay proved invaluable in pinpointing spawning locations within Echo Bay and identified an interesting, cyclical, diel migration of spawning fish to/from deeper portions of the lake during daylight hours, followed by consistent crepuscular/nighttime habitat use of spawning habitats in the back of Echo Bay. Also noted was the utilization of Rogers Bay by the Echo Bay fish, confirming that Rogers Bay continues to serve as an important location for the Echo Bay population, particularly during the nonspawning months.

In addition to stocking sonic-tagged Floyd Lamb razorback sucker into Las Vegas Bay and Echo Bay, 3 of the 10 individuals from the 2005–2006 tagging event were stocked at Fish Island near the Muddy River/Virgin River inflow area. Although none of these fish displayed the extensive migratory behavior that was displayed by the residual fish (code 222) from the 2004 tagging event, interesting utilization of riverine habitats within the Muddy River proper was observed. The fish were also useful in determining adult and larval sampling locations. For the second time wild, unmarked, adult razorback sucker and resultant larval razorback sucker were collected over spawning habitats located along the Fish Island shoreline. The spawning area shifted somewhat from the area reported in Albrecht and Holden (2005). Instead of spawning activities taking place directly on Fish Island, the spawning area for 2006 was located further north (but along the same shoreline) near the Muddy River. As in 2004–2005, this spawning location was again validated by the presence of larval razorback sucker.

Overall, the range of depths occupied by sonic-telemetered fish ranged from less than 2 ft to more than 78 ft, with an approximate mean depth (November–June) of 20 ft. Interestingly, sonic-telemetered fish in Las Vegas Bay, Echo Bay, and the Overton Arm did not show differences in depths used according to the sex of the individual tagged fish during 2005–2006 (Figure 10). However, Echo Bay telemetered fish tended to occupy more profundal locations (ANOVA, $p<0.001$, Tukey post hoc test) (Figure 11), which was likely the result of the unique diel migration pattern observed there (see above). To date, 9 of 10 sonic-tagged fish from 2005–2006 were active, as was a single fish from the 2004 tagging event. With projected declines in lake levels through 2007 (Figure 12), continued tracking efforts should prove to be key in identifying what, if any, habitat shifts are associated with the spawning activities of the various populations of razorback sucker in Lake Mead.

Larval Sampling

Sampling for razorback sucker larvae was initiated in February 2006. Larvae were first collected on February 6, 2006, at Las Vegas Bay on a gravely point located on the western shoreline and within 25 m of several of the five sonic-tagged fish released this field season. At Echo Bay, the first razorback sucker larvae were captured on March 13, 2006, in a small cove along the northern shoreline at last year's reported 2005 spawning area. In contrast, at the Muddy River/Virgin River inflow areas, the first razorback sucker larvae were captured on April 12, 2006, along the northernmost reaches of the Fish Island shoreline, near the inflow of the Muddy River. The last larval razorback sucker (lake wide) was collected on May 1, 2006, at Las Vegas Bay (Table 4). Typically, 8 to 12 monitoring sites at Echo Bay, Las Vegas Bay, and the Muddy River/Virgin River inflow area were sampled weekly (with few exceptions) during February, March, April, and part of May 2006. The number of razorback sucker larvae collected at Las Vegas Bay was much higher in 2006 (Table 4) than in 2005, 2004, and 2003 (257, 76, 4, and 73, respectively), with the majority of larvae being collected along the western shoreline of Las Vegas Bay and confirming a shift in spawning location. Overall, the catch per minute (CPM), or the number of fish captured per minute of sampling of razorback sucker larvae at Las Vegas Bay, was similar in 2005 and 2006 (0.13 vs. 0.12, respectively). However, compared to 2004 or 2003, the CPM in 2006 was much higher (0.003 and 0.06, respectively). Larval capture and sample locations are shown for Las Vegas Bay in Figure 13.

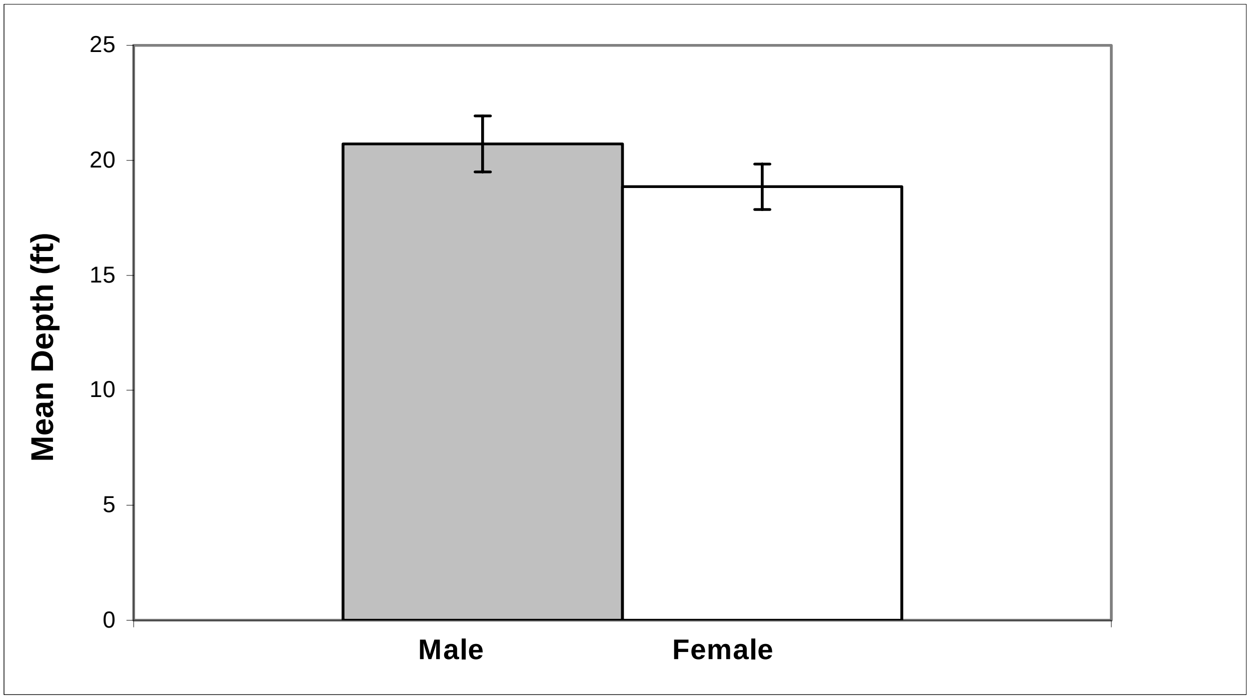

Figure 10. Sonic-telemetered fish depth preferences by sex. No statistical deviance was found in depth preferences between sexes.

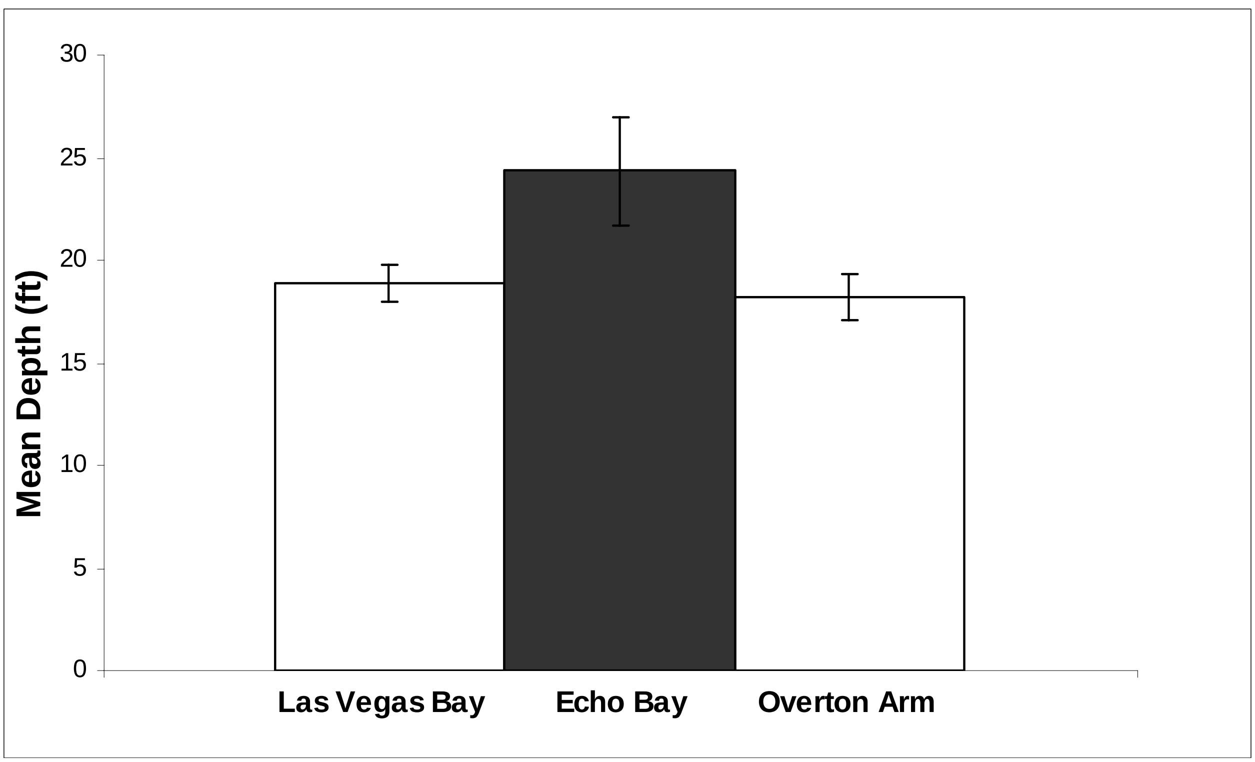

Figure 11. Sonic-telemetered fish depth preferences by lake location. Black bar for Echo Bay indicates a statistically significant difference in depth utilization by sonic-tagged fish occupying this study area.

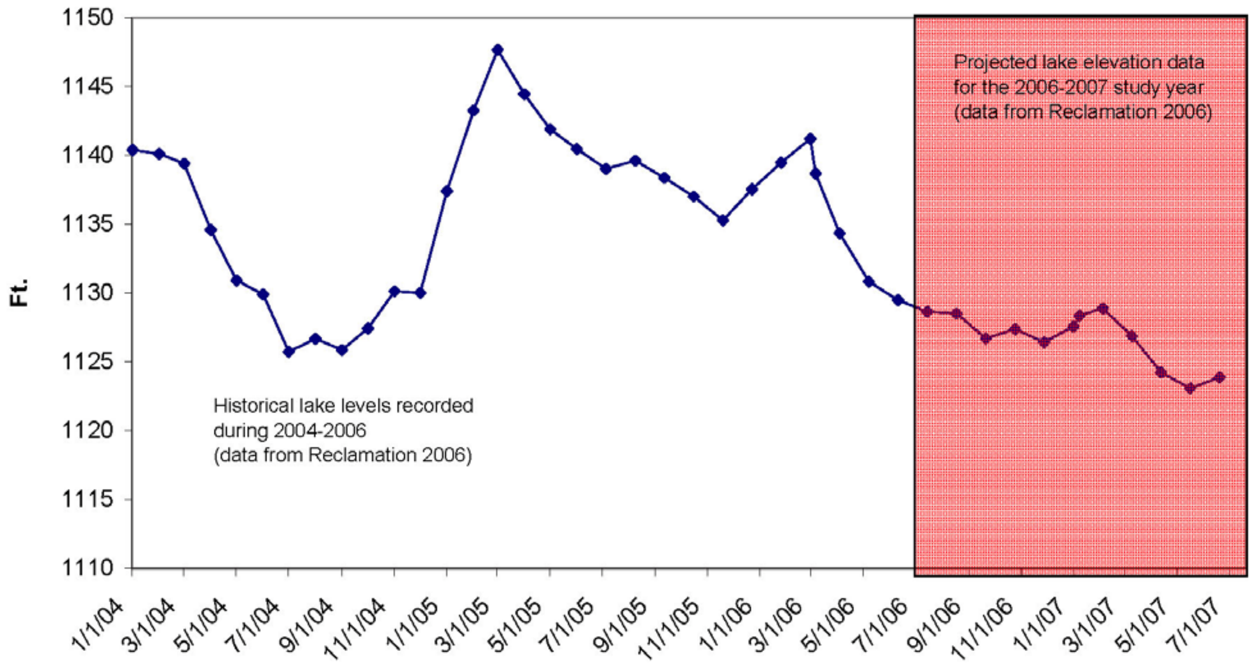

Figure 12. **Lake Mead elevations using a combination of actual, recorded, and historical lake elevation data, as well as projected lake elevation data for the 2004–2007 period.**

The number of larvae collected at Echo Bay in 2006 was lower than the number collected in 2005, higher than in 2004, and lower than in 2003. During 2006, 250 larvae were collected at Echo Bay compared with 1,330 larval fish collected in 2005. In comparison, 207 razorback sucker larvae were collected during 2004, and 552 were collected during 2003. The 2006 CPM at Echo Bay was lower than in 2005, higher than in 2004, and lower than in 2003 (0.29, 1.36, 0.15, and 0.43, respectively). Compared with Las Vegas Bay, larval captures in Echo Bay were delayed approximately 1 month. This may be attributed to localized, cooler water temperatures coupled with the dynamics of lake-level fluctuation differences between the two study areas. Larval catches at Echo Bay appeared to peak during the end of March and beginning of April (Table 4). As in 2005, BIO-WEST teamed with biologists from NDOW, Reclamation, and SNWA to collect additional larval razorback sucker for future repatriation efforts. Larval catches provided for this report only include catches made by BIO-WEST during standard/historical sampling efforts and do not reflect the larval fish collected for hatchery rearing in collaboration with NDOW, Reclamation, and SNWA personnel. Larval fish are currently being held and reared by NDOW, and BIO-WEST continues to work with NDOW to design experimental stocking procedures and monitoring strategies. Larval fish were also collected from Las Vegas Bay during collaborative efforts. The larval razorback sucker sample and capture sites for Echo Bay are shown in Figure 14.

Table 4. Number of razorback sucker larvae collected at the Las Vegas Bay, Echo Bay, and Muddy River/Virgin River inflow areas of Lake Mead during 2006.

DATE	LAS VEGAS BAY SAMPLING SITES			ECHO BAY SAMPLING SITES			MUDDY RIVER/ VIRGIN RIVER INFLOW SAMPLING SITES		
	Minutes Sampled	Larvae Collected	CPM [a]	Minutes Sampled	Larvae Collected	CPM	Minutes Sampled	Larvae Collected	CPM
2/06/06	180	1	0.06						
2/07/06				180	0	0.00			
2/08/06							180	0	0.00
2/13/06	210	102	0.49						
2/14/06							120	0	0.00
2/15/06				180	0	0.00			
2/20/06	180	18	0.10						
2/21/06							180	0	0.00
2/22/06				180	0	0.00			
2/27/06	150	3	0.02						
2/28/06				210	0	0.00			
3/01/06							210	0	0.00
3/02/06				60	0	0.00			
3/13/06	180	20	0.11	90	11	0.12	150	0	0.00
3/20/06				180	18	0.10			
3/22/06	240	25	0.10						
3/27/06				240	56	0.23			
3/29/06							180	0	0.00
3/30/06	180	54	0.30						
4/03/06	180	11	0.06						
4/04/06				30	0	0.00			
4/05/06				30	35	1.17			
4/11/06				30	60	2.00			
4/12/06	240	10	0.04				180	1	0.006
4/17/06							180	4	0.02
4/19/06	150	5	0.03						
4/20/06				180	43	0.24			
4/24/06	210	8	0.04						
4/25/06				150	12	0.08			
4/26/06							180	0	0.00
5/01/06				150 [b]	15	0.10			
Totals	**2100**	**257**	**0.12**	**1,890**	**250**	**0.29**	**1,560**	**5**	**0.003**

[a] CPM = Catch per minute.
[b] On this date one half of the effort was expended at Rogers Bay, although no fish were collected there.

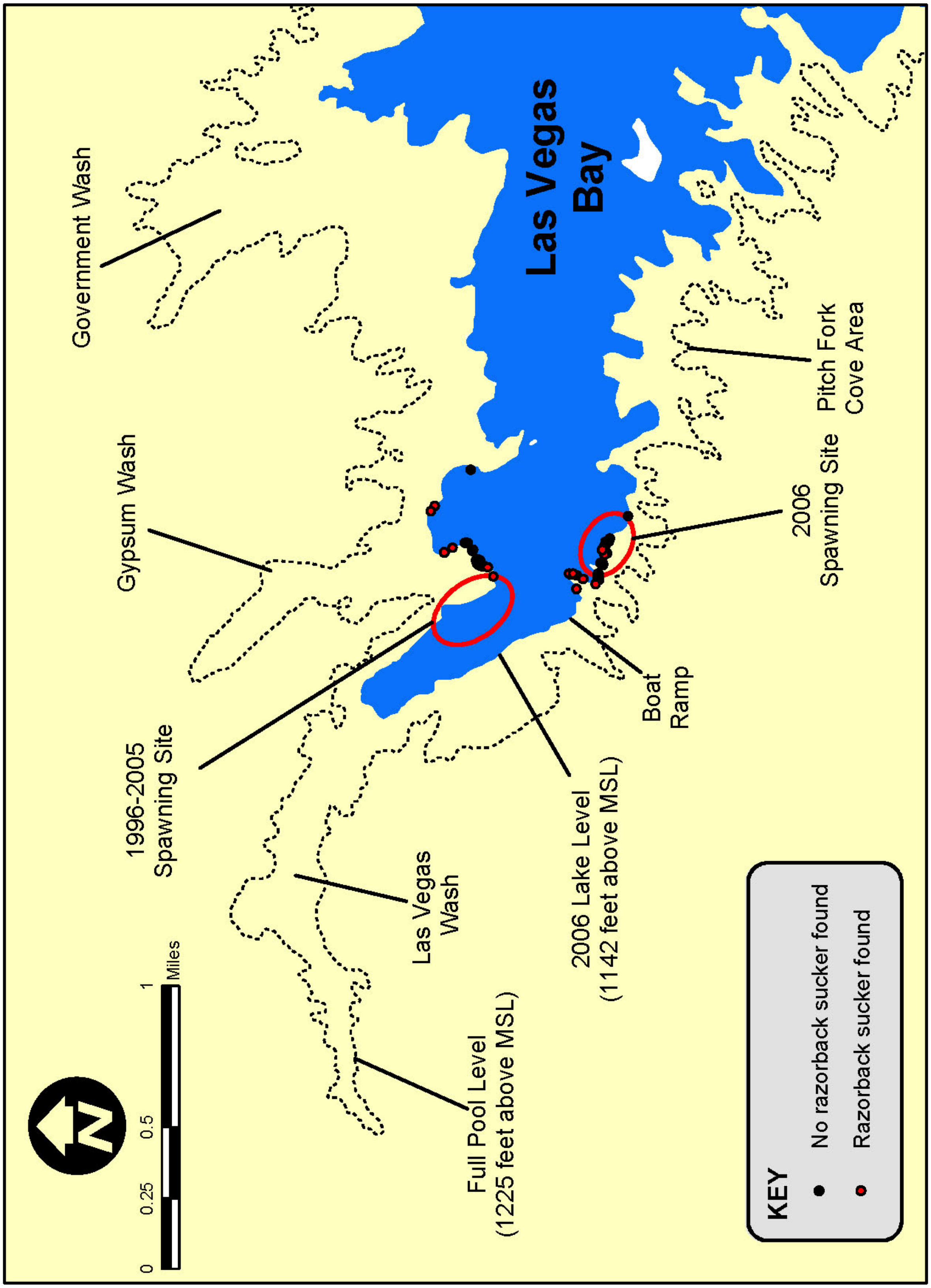

Figure 13. Las Vegas Bay study area showing larval razorback sucker sample and capture locations, 2006.

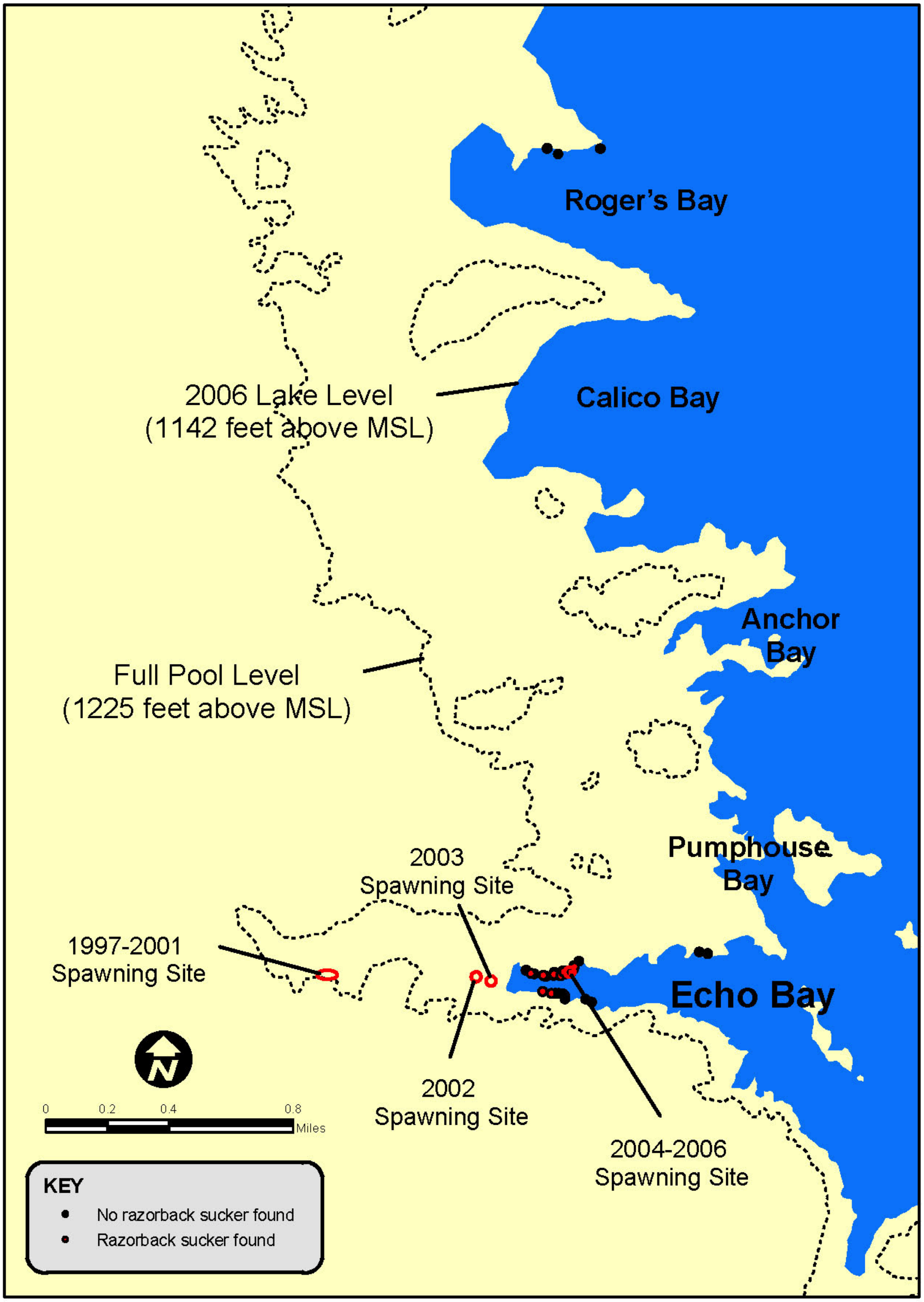

Figure 14. **Echo Bay study area showing larval razorback sucker sample and capture locations, 2006.**

In 2006 larval razorback sucker larvae were collected for the second consecutive year along the Fish Island shoreline, validating suspected spawning in the area, which was a highlight of the 2005–2006 field season. Shortly after the capture of several adult razorback sucker suspected to be spawning near the Muddy River vicinity, BIO-WEST personnel began capturing limited numbers of razorback sucker larvae. Larval sampling was initiated in order to confirm that spawning was actually occurring in this new area and ensure that adult fish were not simply utilizing these new habitats as feeding or resting locations. All larvae in 2006 were collected at points situated along the northern end of the Fish Island shoreline, near the confluence of the Muddy River. Larval catches were limited to a gravel/cobble shelf located just south of the Muddy River, an area of high turbidity in close proximity to vast expanses of inundated vegetative cover associated with the Muddy River inflow area. Captures followed regular utilization of this area by four sonic-telemetered fish and the trammel netting captures of an adult wild, ripe, unmarked female, one of the 2005–2006 sonic telemetered fish, and a repatriated Floyd Lamb State Park fish that was released into Echo Bay in 2002 but was not recaptured until 2006 near the Muddy River (this repatriate has never been recaptured at Echo Bay). In total, five larval razorback sucker were captured near the adult capture locations during April. We hypothesize that stormy/windy conditions prior to and surrounding the capture of the reported larval fish, coupled with lake-level fluctuations, hindered additional capture efforts by both dispersing larval fish and decreasing our effective visual-oriented sampling techniques. Capture of larvae occurred April 12 and 17, 2006. The 2006 larval CPM at the Muddy River/Virgin River inflow area was 0.003, compared with a catch rate of 0.05 during the 2004-2005 study year (Table 4 and Figure 15).

Annual Spawning Site Identification

Decreasing lake levels during the last six study years influenced habitat conditions in all areas where razorback sucker sampling activities have occurred during this 10-year study. From the 1997–2001 originally documented spawning site, the Echo Bay razorback sucker population has shifted spawning locations east (down the bay) as water levels have declined over the past few years. The most recent (2004–2006) spawning location was positioned on a gravel/cobble point located on the northern side of the Echo Bay shoreline, west approximately 0.25 to 0.5 mile from Echo Bay Marina, Echo Bay Launch Ramp, and the associated docking structures.

Similar to previous study years, decreases in water-level elevation continued to affect study activities associated with the Las Vegas Wash area. As in past study years, considerable sampling activity was conducted at or near the confluence of Las Vegas Wash and Las Vegas Bay, at or around the historical Blackbird Point spawning location. This particular location continued to undergo changes in both geomorphic configuration and location relative to the effects of lake elevation as an artifact of sedimentation and wash-related flow processes. When the study began in 1996, the lake elevation was about 1,192 ft amsl. This allowed for substantial wetland-type areas to exist, largely comprised of bulrush (*Scirpus* spp.), cattail (*Typha* spp.), and inundated tamarisk (*Tamarix* spp.) at the point of inflow. Further upstream of the inflow area,

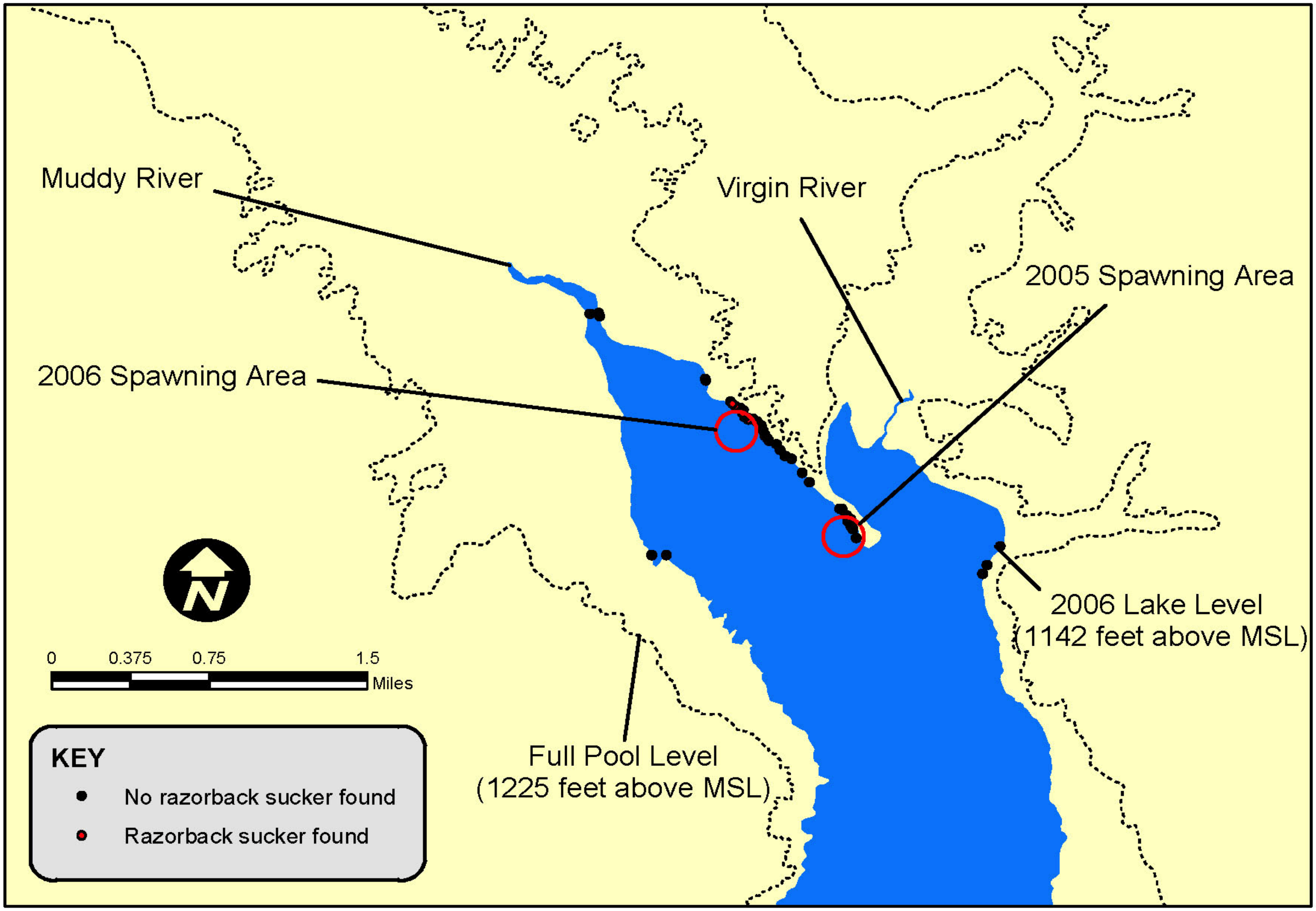

Figure 15. **Muddy River/Virgin River inflow (Fish Island) area showing larval razorback sucker sample and capture locations, 2006.**

the wash was accessible by boat because of a lake-induced back-flow effect. Lake elevation rose approximately 20 feet during 1996 and 1997, thereby inundating this area and causing a delta to form further upstream at a relatively new inflow area. Later, during 1999 and early 2000, increasing amounts of sediment continued to move downstream, filling in a major portion of the bulrush and tamarisk area that was exposed at the beginning of the study in 1996. Additionally, a new delta was formed, effectively limiting boat travel into the flowing, channelized portion of the wash. Similar changes continued during 2001–2005, further defining and enlarging the Las Vegas Wash delta. The continued overall decrease in lake levels affected the Blackbird Point spawning location by further extending the wash delta into Las Vegas Bay. As lake levels decreased and the wash continued to transport large amounts of sediment toward the lake, the riverine section of the wash continued to increase in size and extend in a southerly direction.

Most recently, during the 2005–2006 study year, the historical spawning location on Blackbird Point became completely desicated and was inundated by sediment from the wash terminus, effectively eliminating this location as a spawning area. As a result, we observed spawning in a new location in Las Vegas Bay. This area is located along the western shoreline of Las Vegas Bay, approximately 500 m south of the wash inflow area. It was confirmed as a spawning area by the presence of adult, subadult, and larval razorback sucker, sonic-telemetered razorback sucker habitat movements, and visual observation of a single adult fish. This shift from Blackbird Point to the western shoreline is the first known deviation in spawning location of the Las Vegas Bay population and is likely attributable to the dessication and sedimentation of the Blackbird Point spawning area due to lowered lake levels and the associated dynamics of Las Vegas Wash and its delta.

Much remains to be learned about the effects of lake level on the newly discovered spawning location at the Muddy River/Virgin River inflow area of Lake Mead. Questions remain unanswered regarding whether this location is used by spawning razorback sucker on an annual basis or the area remains suitable spawning habitat at higher lake elevations. Monitoring and research efforts in this portion of the lake may allow determination of the effect of fluctuating water levels on the characteristics of turbidity, hydrogeology, and vegetative cover in this interesting and relatively understudied portion of Lake Mead.

In all, we have found that the best and most effective way to identify and pinpoint annual spawning sites is to utilize a multiplicity of methodologies. The basic and most effective spawning site identification procedure has been to use sonic-telemetered fish, keying in on areas most heavily frequented by tagged individuals. Once a location is identified as an area of heavy use by tagged individuals, nets are then set in an effort to capture adult razorback suckers, which are evaluated for signs of ripeness indicative of possible spawning. After the initial identification of a possible spawning site through sonic-tagged razorback sucker habitat use and other, untagged adult trammel net captures, larval sampling is conducted to validate whether successful spawning occurred. When conditions are conducive, underwater video has been useful in locating specific redds and documenting individual spawning sequences. Examples of the effectiveness of these techniques are evident in the descriptions provided by Albrecht and

Holden (2005) regarding the documentation of a new spawning aggregate near Fish Island. Most recently, these techniques enabled documentation of the first known shift in habitat use by the Las Vegas Bay population (as described above).

Lastly, lake level fluctuations also have implications for selecting potential sites that may provide potential opportunities for stocking and repatriation efforts. As mentioned previously, diminished lake levels have currently isolated Driftwood Cove and Grand Wash Bay from the mainstem Colorado River and Lake Mead Proper (see below for more information). If a new population is started near the Colorado River through repatriation efforts, it is likely that continued utilization of sonic telemetry, adult netting, and larval sampling will be invaluable in describing habitat use and ultimately identifying potential annual spawning locations.

Razorback Sucker Aging

Determination of Lake Mead razorback sucker age distribution was added to the project in 1998, when a subadult fish (381 mm TL) was collected and subsequently died (Holden et al. 1999). This initiated development of a nonlethal aging technique using fin ray sections beginning in 1999 (Holden et al. 2000a). As in past years, an emphasis of our 2005–2006 efforts involved collecting fin ray sections from razorback sucker for aging purposes.

Thirteen of the razorback sucker collected by trammel netting on Lake Mead by the 2005–2006 sampling period had fin ray sections surgically removed for age determination. A definitive age was obtained for all 13 fish (Table 5 and Figure 16). Six of the 13 specimens were aged at 7 years or less, with the remainder aging between 12–33 years. Interestingly, the oldest fish aged this year was a large, ripe, wild, female razorback sucker that was captured from the Muddy River/Virgin River spawning area and was determined to be 33 years of age, making it one of the oldest razorback sucker processed during this study. Also of interest were five very young fish collected from Las Vegas Bay. All of these fish were positively aged and had been spawned from 2000 to 2002, according to back-calculation techniques. This marks the first time that aged Lake Mead razorback sucker had been spawned after 1999, suggesting a continued pattern of low-level recruitment in Lake Mead, even during relatively low lake elevation years.

Table 5 shows the results of efforts for the 78 fish previously aged and the additional 13 fish aged in 2006. Figure 16 shows the number of razorback sucker recruits per year plotted against Lake Mead elevations from January 1935 to June 2006. All of the fish aged were spawned between 1974 and 2002, with the exception of 1 fish that was spawned around 1966. The majority of these fish were spawned during high-lake elevations from 1978–1989 with another, apparently strong razorback sucker cohort, originating during the 1997–1999 period.

Table 5. Ages determined from razorback sucker pectoral fin ray sections collected from Lake Mead.

DATE COLLECTED	TOTAL LENGTH (mm[a])	AGE	PRESUMPTIVE YEAR SPAWNED
		LAS VEGAS BAY	
05/10/1998	588	10[b]	1987
12/14/1999	539	13	1986
12/14/1999	606	17+	1979–1982
12/14/1999	705	19+	1977–1980
01/08/2000	650	18+	1978–1981
02/27/2000	628	17+	1979–1982
01/09/2001	378	6	1994
02/07/2001	543	11	1989
02/22/2001	585	13	1987
12/01/2001	576	8–10	1991–1993
12/01/2001	694	22	1979
12/01/2001	553	10	1991
02/02/2002	639	16	1985
03/25/2002	650	22	1979
03/25/2002	578	10–11	1990–1991
03/25/2002	583	22–24	1977–1979
03/25/2002	545	20[c]	1982
03/25/2002	576	20	1982
05/07/2002	641	15	1986
06/07/2002	407	6	1995
06/07/2002	619	20[c]	1982
06/07/2002	642	20[c]	1982
12/03/2002	354	4	1998
12/06/2002	400	4	1998
12/06/2002	376	4	1998
12/19/2002	395	4	1998
01/07/2003	665	16	1986
01/22/2003	494	4	1998
02/05/2003	385	4	1998
02/18/2003	443	5	1997
03/04/2003	635	19	1983
03/20/2003	420	4	1998
04/08/2003	638	21[c]	1982
04/17/2003	618	10	1992
04/22/2003	650	20–22	1980–1982
05/04/2003	415	3+[b]	1999
03/03/2004[d]	370	5	1998

DATE COLLECTED	TOTAL LENGTH (mm[a])	AGE	PRESUMPTIVE YEAR SPAWNED
02/22/2005	529	6	1998
02/22/2005	546	6	1998
03/29/2005	656	16	1989
01/26/2006	740	15	1991
02/21/2006	621	23	1983
03/23/2006	461	5	2001
03/23/2006	718	16	1990
03/31/2006	635	7	1999
03/31/2006	605	6	2000
04/04/2006	629	6	2000
04/25/2006	452	4	2002
04/25/2006	463	4	2002
	ECHO BAY		
01/22/1998	381	5	1993
01/09/2000	527	13	1987
01/09/2000	550	13	1987
01/09/2000	553	13	1987
01/09/2000	599	12–14	1986–1988
01/27/2000	557	13	1986
01/27/2000	710	19+	1979–1981
02/09/2001	641	13	1988
02/24/2001	577	18+	1980–1982
02/24/2001	570	8	1992
02/24/2001	576	15	1986
02/24/2001	553	18	1983
12/18/2001	672	13	1988
02/27/2002	610	18–20	1982–1984
03/26/2002	623	16	1986
04/02/2002	617	35+	1966–1968
04/17/2002	583	20[c]	1982
05/02/2002	568	18–19	1983–1984
11/18/2002	551	13	1989
12/04/2002	705	26	1976
01/21/2003	591	16	1986
02/03/2003	655	27–29	1974
02/03/2003	580	13	1989
04/02/2003	639	19–20	1982
04/02/2003	580	23–25	1978
04/23/2003	584	10	1992
05/06/2003	507	9+	1993
05/06/2003	594	20	1982

DATE COLLECTED	TOTAL LENGTH (mm[a])	AGE	PRESUMPTIVE YEAR SPAWNED
12/18/2003	522	20	1982
01/14/2004	683	14	1989
02/18/2004	613	10	1993
03/17/2004	616	19	1983
03/17/2004	666	17	1985
03/17/2004	618	9	1994
04/06/2004	755	17	1985
03/02/2005	608	15	1990
03/02/2005	624	8	1996
01/10/2006	630	12	1994
02/01/2006	705	16	1990
02/16/2006	601	22	1984
	FISH ISLAND		
02/23/2005	608	6	1998
02/22/2006	687	33[d]	1973

[a] mm = Millimeters.
[b] Fish stocked from Echo Bay larval fish captured in 1999 and raised at Nevada Department of Wildlife Lake Mead Fish Hatchery.
[c] Fish stocked from Floyd Lamb State Park ponds (1982 Dexter National Fish Hatchery cohort placed in Floyd Lamb State Park ponds in 1984).
[d] Fish was aged at 33 years of age, +/- 2 years.

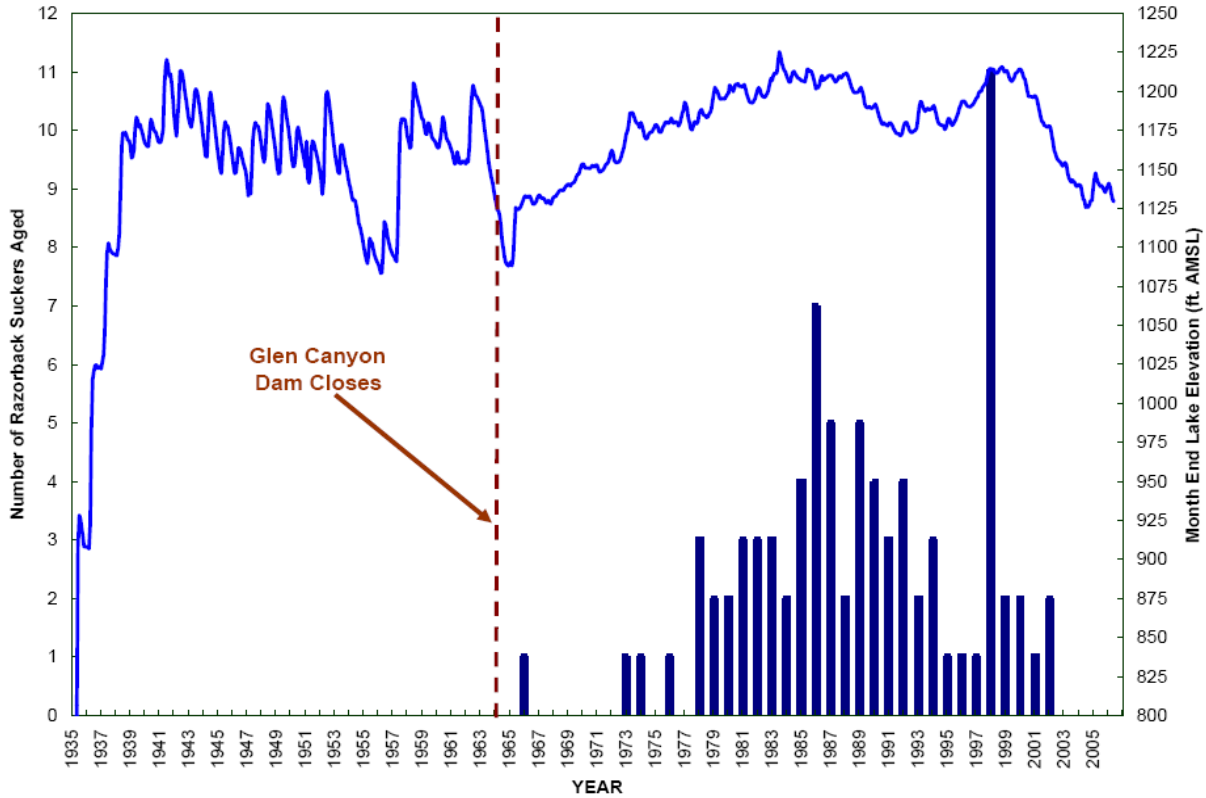

Figure 16. Lake Mead hydrograph from January 1935 to June 2006 with the number of aged razorback sucker that were spawned each year.

Population Estimate

Table 6 shows the results of the population modeling using the two models from the program CAPTURE (Rexstad and Burnham 1992), as well as estimates from the model selection procedure. Echo Bay razorback sucker estimates ranged from a low of 38 fish to a high of 74 fish during 2004–2006. Las Vegas Bay estimates were higher than those of Echo Bay, ranging from a low of 40 to a high of 267 fish (the estimate of 267 has an extremely large confidence interval).

Population abundance remains highly variable at both study areas, and any patterns are therefore difficult to distinguish. It should be noted that this year's data and last year's data from Echo Bay, and to some extent data from Las Vegas Bay, tended to be somewhat anomalous as netting and number of captures were likely reduced because approximately one-third of the field crew's efforts were expended investigating the Fish Island area. As a result, population estimates for the Echo Bay and Las Vegas Bay populations should be cautiously interpreted and compared

Table 6. Population estimates using data from 2004-2006.

ESTIMATOR	2004–2006	95% CONFIDENCE INTERVAL
	ECHO BAY	
Model M_o	47	39–66
Chao M_h	46	38–74
Model Selection Procedure		
Jackknife	40	40–67
	LAS VEGAS BAY	
Model M_o	70	40–156
Chao M_h	91	43–267
Model Selection Procedure		
Jackknife	77	49–138

with past findings; they should not be viewed as trend data, particularly given the violation of many of the assumptions involved with closed population estimation techniques and the dramatic differences in effort expended within/between years (see discussion section below). Given the wide variability of the population estimates provided over the years, perhaps an additional indication of relative population trends on Lake Mead can be gleaned from the annual trammel netting CPUE, which has been expressed as the number of fish collected per net night in this and other annual reports. Similar to annual population estimates, CPUE tends to be variable over time and is likely influenced by our ability to consistently sample and capture fish across study years, particularly as reservoir and habitat conditions change from year to year (Figure 6).

Lastly, population estimates for the new spawning aggregate at Fish Island were not calculated due to the scarcity of data collected to date. Furthermore, it remains unknown whether Echo Bay and Fish Island populations are two distinct units, or if razorback suckers collected near the Muddy River/Virgin River inflow area are simply an extension of the Echo Bay spawning aggregate. However, the CPUE reported this year (0.08 fish/net night) is nearly identical to that found during the 2004–2005 spawning season (0.07 fish/net night) (Figure 6). As more effort is expended in this location, future population estimates may be possible, if deemed useful by collaborators.

Potential Stocking/Repatriation Opportunities

A new objective for the 10th study year was to look for opportunities within Lake Mead for development of new populations using stocked/repatriated fish. The working hypothesis for this objective was that recruitment in any one location in Lake Mead can likely only support relatively small populations, and hence development of additional small populations will be needed to increase the Lake Mead razorback sucker population. In addition, we hypothesized that only a relatively few number of coves/bays/locations in the lake are suitable for sustained recruitment. This hypothesis was developed by evaluating the results of the first 9 years of study on Lake Mead. Razorback populations in Lake Mead are now relatively small but are sustained by natural recruitment. Stocking of fish adds to the adult population size but appears to do little for recruitment, which seems dependent on suitable habitat availability. Such habitat appears to be bays with relatively high densities of vegetative cover during high-flow years and relatively high turbidity levels. Our past studies suggest that inflow areas generally meet the criteria for recruitment and that the Colorado River inflow area is a likely candidate for development of a new population.

Because razorback sucker stocked into the lake demonstrate a tendency to wander until they find an existing population, developing a new population is problematic. Razorback sucker tend to return to their natal spawning areas; thus imprinting may also be an important part of the population development task (Sholtz et al. 1992, 1996). These factors suggest that potential new population areas need to have necessary recruitment habitat, yet be capable of holding adult fish until they spawn, after which the young will hopefully imprint on that location and return to spawn if they survive. The ideal location will be a bay that is either naturally or artificially cut off from the lake, one that can be manipulated with piscicides to eliminate impacts of nonnative predators, is near areas with recruitment habitat, and can hold fish for several years to allow naturally spawned young a chance to grow large enough to avoid predation. This information, along with other applicable findings could hypothetically diminish the need and costs associated with continued, repeated stockings of hatchery-reared razorback sucker.

Several bays in the Colorado River inflow area have possessed some of these characteristics over the past several years as the lake has receded. Many of the bays, such as Pearce Ferry Bay, were temporary and were too shallow to support razorback sucker for several years. Aerial reconnaissance of the upper lake in late 2005 suggested that two bays may fit the criteria noted above, Grand Wash Bay and Driftwood Cove. Both locations are near the Colorado River and would be connected to the main body of the lake at higher lake elevations, although they are presently isolated or cut-off from the lake proper. Additionally, in the past several larval razorback sucker were collected from this portion of the lake, indicating the potential for future population spawning and perhaps even recruitment.

Once the two potential locations were identified, several methodologies were applied during two different trips to evaluate both the physical and biotic components of these isolated bays. Measurements ranged from visual, qualitative investigations and GIS areal calculations, to water quality sampling and gill netting to evaluate present fish community composition.

Initial Reconnaissance Trip

On February 7, 2006, BIO-WEST collaborated with Reclamation personnel and investigated the Driftwood Cove and Grand Wash Bay sites. Because of lowered lake conditions, a Reclamation jet boat was utilized to gain access to the areas of interest. At Driftwood Cove, water quality profiles were obtained using a Hydrolab. In addition, size, depth, and substrates were qualitatively explored, and the logistical requirements for accessing the area were obtained. During the on-site visit to Grand Wash, it became evident that the immense size of the bay made it infeasible to manage/manipulate, but the bay would be an excellent site if provided with substantial resources and support. In contrast, it was the general consensus of the participating collaborators that Driftwood Cove could provide a more manageable option (Figures 17, 18).

Driftwood Cove water quality parameters were satisfactory for all variables sampled. Oxygen levels ranged from 10 mg/L at the surface to 8.4 mg/L at the bottom. Conductivity throughout the water column was approximately 2,450–2,460 microsiemens per centimeter (µS/cm). Temperatures were a constant 10 ^{o}C at all depths. The secchi depth was 1 m. In addition, the cove was well connected to the river at a lake elevation of nearly 1,140 ft (amsl). At the conclusion of the trip, aerial photographs were taken during August 2004 (lake elevation of approximately 1,124 ft amsl) were used to calculate the area of both Driftwood Cove and Grand Wash Bay using GIS technology. Driftwood Cove was calculated to be 109.4 acres, while Grand Wash Bay was more than an order of magnitude larger at 1,230 acres. It was estimated that Driftwood Cove would become completely disconnected from the river at a lake elevation of approximately 1,135 ft amsl.

Interagency Investigative Trip

An interagency field investigation was organized, and collaborating agencies performed an evaluation of the Driftwood Cove site May 8–9, 2006. Personnel from AGFD, Reclamation, SNWA, NPS, NDOW, and BIO-WEST participated. The overall purpose of the collaborative effort was to determine the feasibility of removing existing nonnative fish from the cove in an effort to create a grow-out area for potential repatriation/stocking efforts, evaluate the logistics of accessing the site, and evaluate the overall size of the potential habitat that could be created. The repopulation effort could provide opportunities for further experimentation regarding issues of imprinting, creating new populations, and further testing recruitment patterns and related hypotheses associated with Lake Mead razorback sucker investigations to date.

Driftwood Cove was again accessed using a Reclamation jet boat, while on-site surveys were accomplished using a small jon boat equipped with an electric trolling motor provided by AGFD. Both 150 ft nylon mesh and 100 ft monofilament mesh gill nets with mesh sizes of 1–2 in were deployed to sample the Driftwood Cove fish community composition. In all, three nets were set at dusk and retrieved the next day. In addition, water quality was assessed using a Hydrolab at two different locations. Water quality profiles were obtained in 1 m depth intervals and taken at dusk. In addition, the river/cove connection was investigated to evaluate whether there was complete isolation or isolation of the cove would likely occur in the near future.

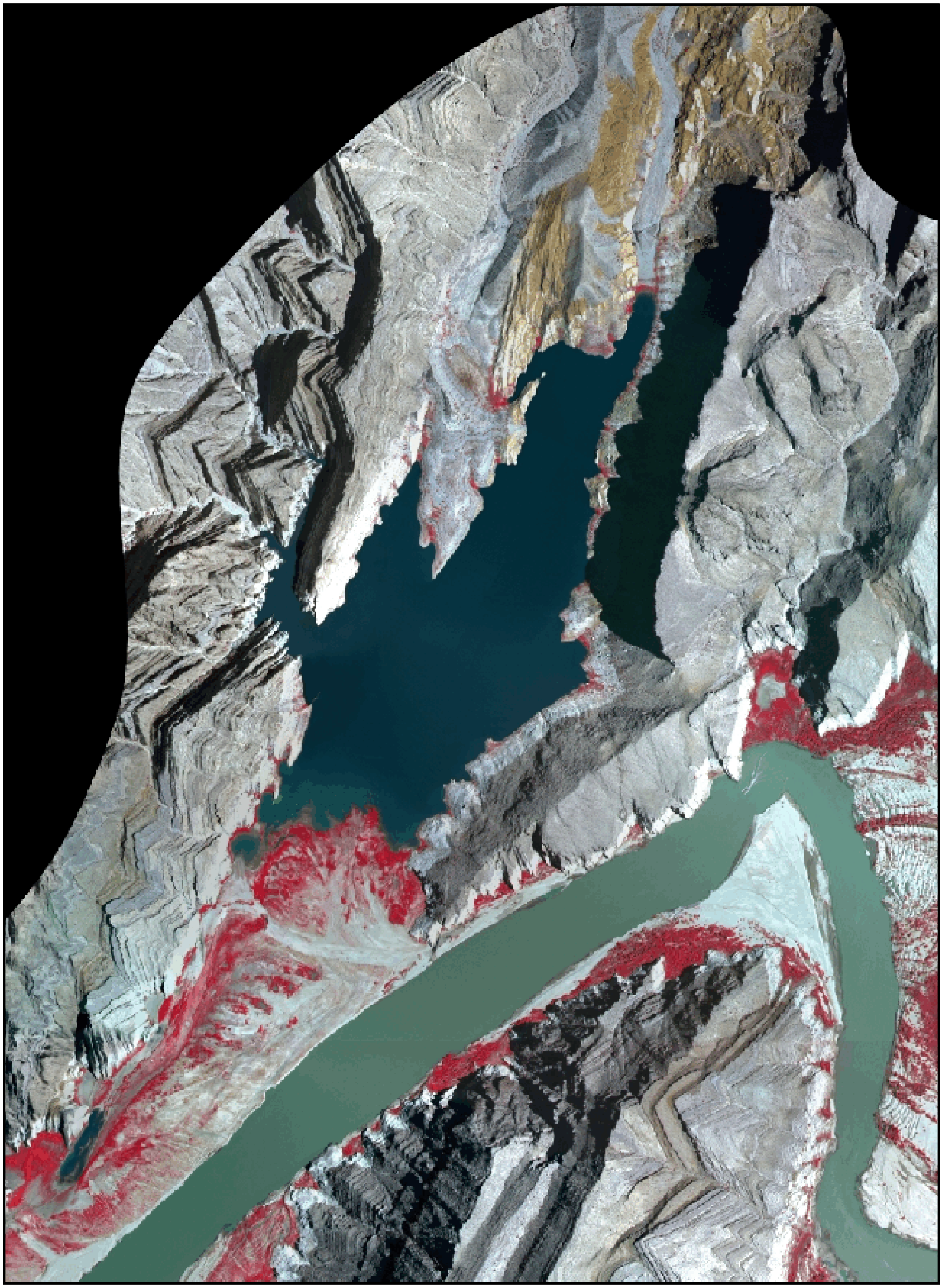

Figure 17. Aerial photography of Driftwood Cove (obtained August 2004 at lake elevation of approximately 1,124 ft amsl). Imagery scale is 1:12,000.

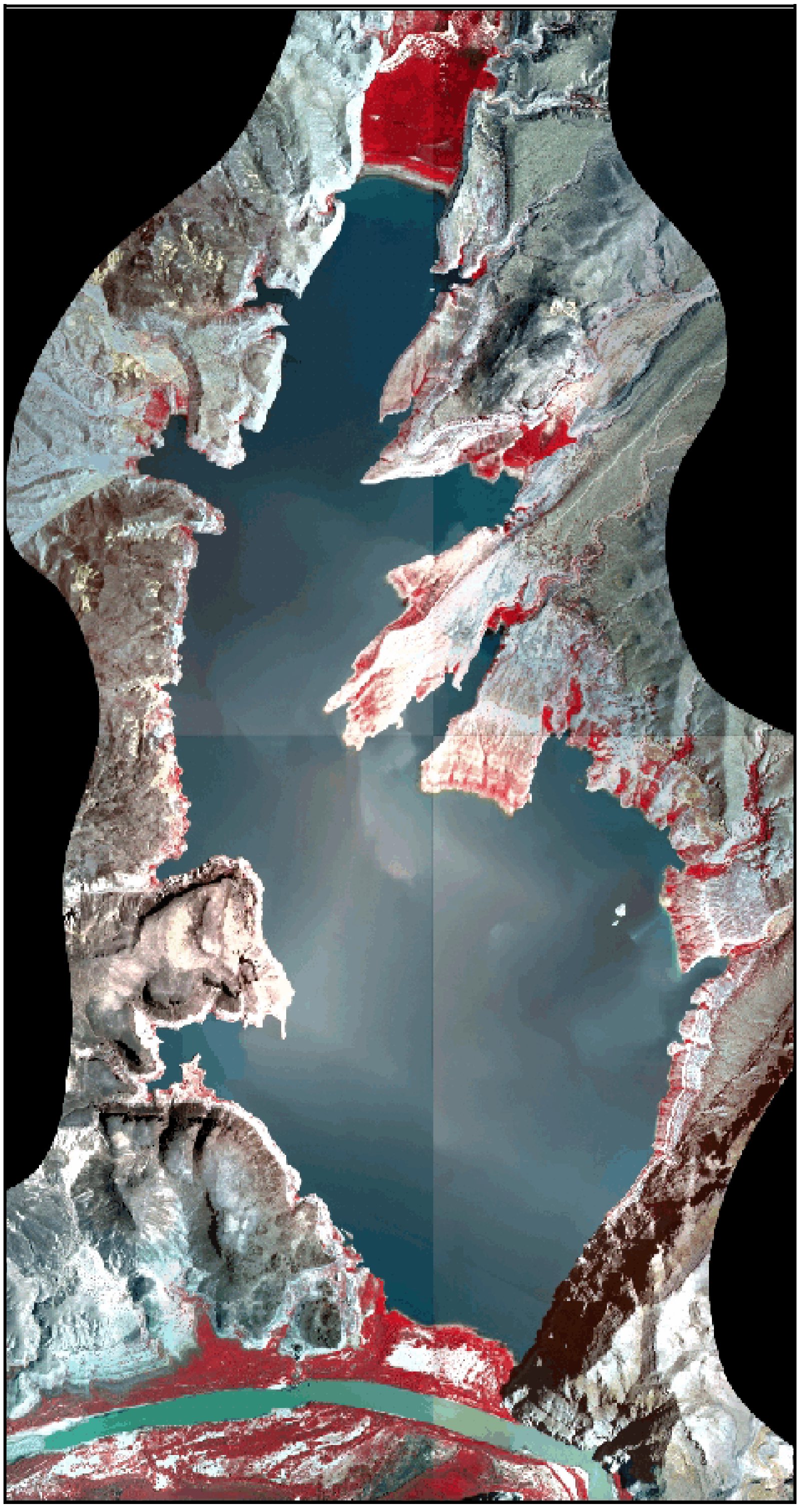

Figure 18. Aerial photography of Grand Wash Bay (obtained August 2004 at lake elevation of approximately 1,124 ft amsl). Imagery scale is 1:25,000.

During the second site visit, 51 fish were collected during one net night of gill netting. Species collected included common carp, channel catfish, striped bass (*Morone saxatilis*), yellow bullhead (*Ameiurus natalis*), and blue tilapia (*Oreochromis aureus*) (Figure 19).

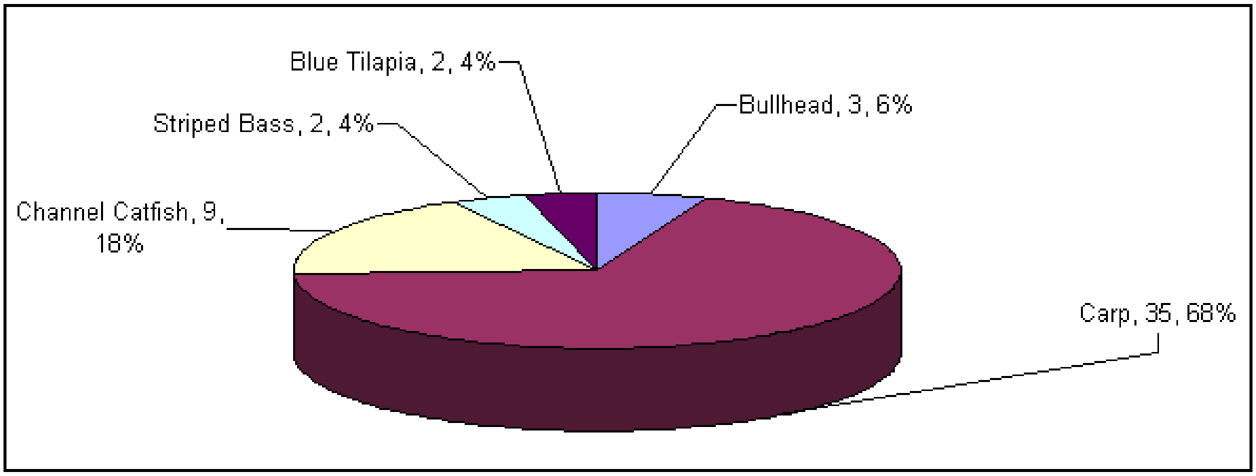

Figure 19. Species composition of interagency collaborative gill netting efforts at Driftwood Cove (May 2006).

During the May trip, surface temperatures ranged from 25 ºC at the surface, to 21 ºC near the bottom of the cove. Dissolved oxygen ranged from approximately 9.6 to 2.0 mg/L, depending upon location and depth. Conductivity ranged from 2,470 to 2,420 µS/cm. The pH was variable throughout the cove, ranging from 7.6 at one surface location to 11.1 at the benthos, while it remained near 7 to 8 regardless of depth at other locations. In general, water clarity was estimated at less than 1.0 m. Lake Mead elevation at the time of sampling was approximately 1,135 ft, and the only remaining connection between the cove and river was a very small (less than 0.5 meter-wide by less than 10-centimeters deep) channel flowing out of the southernmost end of the cove. It was projected that another 1 ft decline in lake elevation would completely isolate Driftwood Cove. Projected Lake Mead elevation data obtained from Reclamation (2006) indicate that Driftwood Cove will most likely remain disconnected through November 2007 and possibly beyond. If this occurs, stocked/repatriated fish could have a fairly substantial block of time to imprint on this area and perhaps spawn prior to the reinundation of the cove (Figure 12).

As with all stocking-related efforts, it should be noted that the opportunities outlined above involve a level of risk. One of the items beyond our control is the potential for the lake to rise and reconnect to Driftwood Cove, allowing the stocked/repatriated fish to access the lake proper, perhaps earlier than desired. Another concern is the risk that lake levels could continue to fall and the cove could become desicated or uninhabitable because of water quality problems. This particular risk would require preparation of a salvage plan and regular water quality monitoring of the cove, thereby enabling a rapid response geared towards salvage and removal of stocked fish. Salvaged fish could be returned to the mainstem Colorado River, Lake Mead, or some other predetermined, desirable location. It should also be noted that during interagency investigations, several species of piscivorous birds were observed (e.g., grebes and cormorants), and this should be considered if stockings take place. The last barrier is the comparatively poor access to Driftwood Cove. Access for piscicide treatments would be difficult from the ground; the location appears to be more readily accessible via helicopter. This consideration should be included in the fish salvage plan. Currently, costs and benefits of this potential opportunity are being evaluated, and this apparently time-limited opportunity is being researched by the various interested agencies involved with Lake Mead razorback sucker research and management.

DISCUSSION AND CONCLUSIONS

Information collected during the 10th year of razorback sucker studies on Lake Mead has expanded knowledge on age, growth, habitat use, recruitment patterns, and spawning behavior. In addition, information has been gained regarding age at sexual maturity, the nature of stocked and wild fish interactions, population abundance, and razorback sucker response to increasing lake elevations, particularly at Las Vegas Bay.

Sonic telemetry, trammel netting, and larval collection reaffirmed the importance of Echo and Las Vegas bays to spawning razorback sucker. This combination of methodologies helped to identify continued razorback sucker spawning in the relatively new Muddy River/Virgin River inflow area of Lake Mead and confirmed the importance of river inflow areas to Lake Mead razorback sucker spawning aggregates. Additional data on annual razorback sucker growth confirmed rates documented in previous years, and aging data from 13 adult razorback sucker were added to the data from 78 fish aged from 1998 to 2005, bringing the total number of aged fish to 91 and demonstrating continued recruitment as late as the 2002 spawning period.

Unlike the problems with sonic-telemetered fish during the 2004–2005 study year, continued contact and increased presence of sonic-telemetered fish was normal during the 10th field season. Nine of the 10 Floyd Lamb razorback sucker tagged during the 2005–2006 study year were contacted on a regular basis. These fish enabled our first documentation of a shift in the spawning site of the Las Vegas Bay razorback sucker population from the historical Blackbird Point spawning area to the western shoreline of Las Vegas Bay. As in 2004–2005, Echo Bay sonic telemetry results for fishes 222 and 447 indicated continued use of the northern shoreline of Echo Bay for spawning activities. Overall, the tagging events during 2004–2005 and 2005–2006 using razorback suckers reared in Floyd Lamb State Park have produced remarkable findings. Studies of these sonic-tagged fish initially helped to locate spawning habitat use in the Overton Arm of Lake Mead and identified continued use of the Fish Island shoreline for spawning activities this season. Additionally, substantial razorback sucker movement up the Muddy River proper in the northernmost portions of Lake Mead was documented. These behaviors would have been difficult to ascertain without the experimentation and subsequent monitoring of the tagged Floyd Lamb State Park fish. Future tagging events would most certainly help answer a multitude of questions regarding population intermixing and habitat usage throughout the lake, particularly if repatriation efforts were to increase.

In 2006 the CPM and total number of larvae at Echo Bay were very comparable with other study years, even years when lake elevations substantially surpassed levels recorded during 2005–2006. Larval catch rates were lower at the Muddy River/Virgin River areas during the past field season, compared with the 2005 season, while larval CPM at Las Vegas Bay was much higher than those reported in the last several years. As reported by Welker and Holden (2004), numbers of larvae at both Echo and Las Vegas Bays were declining and had been declining for four consecutive years, which was presumably an artifact of low and declining lake levels. However, the 2005 CPUE was an order of magnitude higher, although the lake only rose approximately 20 feet from the lowest elevation recorded near the beginning of the 2004–2005 study year (Albrecht and Holden 2005). An increasing trend in larval catch rates this season at Las Vegas Bay was likely related to increased contact with sonic-telemetered fish, which in turn helped crews focus on more appropriate sampling locations within Las Vegas Bay, presumably at areas frequented by spawning adults. Interestingly, the results from a number of fish aged during 2000–2002 suggest that some low-level recruitment of razorback sucker on Lake Mead occurs even during low-water years. Future efforts on Lake Mead will help to identify whether recruitment occurred this season despite relatively low lake elevations and, if so, will provide insight regarding the strength of this year's age class.

At Echo Bay the pattern of razorback sucker moving down Echo Bay Wash to spawn as the lake declined was similar to that documented during the previous 3 years. This phenomenon indicates that Echo Bay razorback sucker exhibit spawning site fidelity but possess enough flexibility in their spawning behavior to spawn at alternate locations when the preferred site is inaccessible. This behavior has also been observed in the Green River, Utah (Tyus 1987, Bowen et al. 2001), where different spawning sites were used at different river elevations. During all years of the study, the spawning site at Echo Bay was at a depth of 10 to 20 ft. Since 2004 the spawning site has been at the same location along the northern shoreline of Echo Bay.

During the 2004 spring spawning period (particularly February–April 2004), sediment from Las Vegas Wash affected the remaining portion of the historical Blackbird Point spawning location. At the end of June 2004, the wash delta effectively covered the entire historical Blackbird Point spawning area with sediment. However, lake levels subsequently rose and the associated low larval and adult catch rates during 2004 were replaced with higher results in 2005. Following the slight lake level increase during the 2005 spawning period and the documented reutilization of the Blackbird Point spawning area (Albrecht and Holden 2005), lake levels and sediment movement associated with the delta of Las Vegas Wash made the historical Blackbird Point spawning location inaccessible. These findings highlight the affinity of the Las Vegas Bay razorback sucker population for the historical Blackbird Point spawning area and suggest the importance of lake levels to the razorback sucker population in this area of Lake Mead. In fact, we had not documented Las Vegas Bay razorback sucker spawning anywhere other than Blackbird Point until recently.

In 2006, as a result of the desication and sedimentation of Blackbird Point, coupled with increased ability to locate adult razorback sucker habitat by following five, newly tagged fish, we documented a shift in spawning site selection of the Las Vegas Bay razorback sucker population. During 2006 the Las Vegas Bay razorback sucker population spawned along the western shoreline. Although differential selection of spawning habitats was the norm at Echo Bay, for the first time during the course of our research, a similar shift in spawning habitat use occurred at Las Vegas Bay. While we had speculated internally that the Las Vegas Bay population would make the shift when required, it has now been documented. Evaluating the ramifications of this shift in spawning habitat selection by the Las Vegas Bay population, particularly in terms of recruitment, and identifying how spawning at this new location translates into terms of recruitment will be important in future study years. Furthermore, as continued lake level declines are projected through 2007, it will also be a research/monitoring priority to follow the Las Vegas Bay population's spawning habitat selection to identify any additional spawning sites, shifts, or resumed spawning at Blackbird Point. This will be detailed in the companion report for long-term monitoring.

Efforts in the northernmost portions of Lake Mead near the Muddy River/Virgin River inflow areas provided interesting (though preliminary) findings, but multiple questions remain unanswered concerning this new spawning area. For example, although limited evidence suggests that the Muddy River/Virgin River inflow population interacts at some level with the Echo Bay population, we have yet to capture a wild, PIT-tagged fish from Echo Bay at Fish Island, or one of the wild, PIT-tagged fish from the Muddy River/Virgin River inflow area at Echo Bay. Furthermore, the repatriate that was stocked into Echo Bay in 2002 was captured this season (this fish had not been captured at Echo Bay since its 2002 stocking). As such, there are many unanswered questions regarding fish interaction in this portion of Lake Mead. For example: To what degree is the razorback sucker population at Fish Island independent? Is it simply an extension of habitat usage by the Echo Bay population? Is the Fish Island area used every year, or only at diminished lake elevations? Does spawning occur annually in this area? Do razorback sucker that utilize Fish Island follow recruitment patterns similar to those documented for the Echo Bay and Las Vegas Bay fish? What is the size of the Fish Island population? These and a multitude of other questions emphasize the need to continue sampling in this new, relatively understudied area of Lake Mead. Continued interest in Lake Mead razorback sucker research will enable increased efforts throughout Lake Mead, particularly since a large number of razorback sucker from Lake Mead may soon be repatriated. This research not only provides a unique opportunity to expand knowledge about Lake Mead populations, it may also provide information important for native fish recovery efforts throughout the Colorado River and its impoundments.

Underwater video surveillance in 2005–2006 successfully documented spawning activity at the suspected Echo Bay spawning site. Spawning activities and associated behaviors were recorded at the same location used for spawning by the Echo Bay population over the last several seasons. Underwater videography has proven useful for validating suspected spawning activities, particularly when used in combination with other methodologies such as larval sampling, adult capture techniques, and sonic telemetry. However, typically at Las Vegas Bay and the Muddy River/Virgin River inflow areas, high turbidity from sediment-laden flows limits the effectiveness of underwater video equipment.

Growth rates of recaptured Lake Mead razorback sucker continue to surpass growth rates recorded for other wild razorback sucker populations. Mean annual growth for Lake Mead fish recaptured in 2005–2006 was 10.6 mm, compared with very low growth (less than 2.0 mm per year) for razorback sucker in Lake Mohave (Pacey and Marsh 1998) and the Green River (McAda and Wydoski 1980, Tyus 1987). As indicated in Mueller (2006) these elevated growth rates indicate that Lake Mead razorback sucker populations are relatively young.

In 2001 BIO-WEST sampled during the prespawning and early spawning periods when resident fish and early spawners could be sampled; however, many fish, particularly those that are late spawners, were probably absent from both spawning areas (Holden et al. 2001). During 2002 BIO-WEST sampled during both the spawning (January–May) and nonspawning periods. Nine of the thirteen fish caught during the spawning period were new captures, giving a 69.2% capture rate for previously uncaptured fish. Outside the sampling period, 8 of the 17 fish were new captures. This produced a 47.0% capture rate for previously uncaptured fish. When the catches of both periods were combined, a capture rate of 56.7% was obtained for previously uncaptured fish, which is nearly 27% higher than in 2001. In 2003 razorback sucker were again sampled during the spawning and nonspawning periods and a 42.9% capture rate for previously uncaptured fish was documented. In 2004 a capture rate of 29.4% was observed, while in 2005 we found a capture rate of 25% for uncaptured fish, which is again slightly lower than in 2004. This season, 13 of 47 fish were new captures, providing a capture rate of 27.7% for unmarked fish, a rate slightly higher than in 2005, albeit still relatively low compared with earlier study years. As more fish from these presumably small populations are tagged, the capture rate of previously uncaptured fish may decrease, especially under conditions of low recruitment expected during low lake elevation years. Furthermore, in 2005 and 2006, the decrease in nonspawning season netting likely confounded overall capture-related comparative abilities, particularly as effort was highly variable between years.

During the 10th study year, fin-ray extraction aging efforts continued. Calculated ages ranged from 4 to 33 years for the 13 razorback sucker aged in 2006. Ages of the 13 fish evaluated in 2006 and the 78 previously aged fish helped identify that recruitment occurred fairly regularly from 1974 to 2002. The greatest recruitment occurred from 1985 to 1987 and in 1998. Finding several fish aged less than 7 years indicated recent (1990–2002) recruitment to the Lake Mead population. Interestingly, 6 of the 13 fish aged in 2006 (46%) were recruited since 1999, coinciding with the elevated lake levels present during the onset of this study and demonstrating that recruitment is possible even during relatively low and declining water years such as 2001 and 2002. Furthermore, one of the fish collected at the new Fish Island spawning area was aged at 33 years, making it one of the oldest fish collected during our studies and suggesting that the Fish Island spawning aggregate is likely comprised of both young and old individuals. This finding may suggest that the Muddy River/Virgin River inflow area of the lake has been used by spawning individuals for many years, perhaps as long as the Echo Bay and Las Vegas spawning sites, but simply remained undetected until recently.

Since approximately 1974, fin-ray aging data and back-calculation techniques indicated that recruitment of Lake Mead razorback sucker has occurred nearly every year. Known numbers of fish recruited to the population range from a single, individual recruit per year (typically spawned during low-water years) to over 10 individual recruits per year (generally associated with relatively high-water years). Given the typical 100–300 lake-wide population estimates obtained during our study, the longevity of the species, a calculated 13-year mean age of razorback sucker captured to date, and assuming that we are not capturing every recruit, it appears that the generally low yet steady rate and occasional higher pulses of recruitment may approach a recruitment rate necessary for long-term sustainability of this unique population (based on concepts from Mueller 2006). Continued capture of young, recently recruited individuals further supports this idea. Additionally, the idea of a sustainable population of Lake Mead razorback sucker becomes even more probable when assuming that past and present population estimates are conservatively correct. If population estimates are within proximity to the actual number of razorback suckers in Lake Mead, and we can capture 50 individuals on a relatively efficient year of trammel netting, then we are only sampling approximately 15–50 percent of the population during any given study year. As such, it appears that our overall, actual capture rate of new recruits for most years is underestimated by at least 50–85 percent. Hence making the actual numbers of new recruits for any given year to probabilistically be grossly underestimated. Therefore, a self-sustaining population is a very real possibility in Lake Mead. While much about this population remains unknown, the continued presence of wild recruitment in the form of young, sexually immature fish makes the Lake Mead razorback sucker population both a rarity and an anomaly in terms of razorback sucker persistence throughout the Colorado River drainage. This population persists despite nonnative fish composition and densities similar to other locations (Holden et al. 2005). As time passes, we expect to begin capturing a low number of individuals spawned during 2003, 2004, 2005, and even 2006. If/when the lake rises in future years, we also expect to see another pulse in recruitment.

Aging data from the current study year help confirm Albrecht and Holden's (2005) statement that Lake Mead razorback sucker reach sexual maturity at around 6 years of age. For example, all fish (N=3) collected in 2006 that were too young to age at the time of capture ranged between 4 and 5 years old, while two fish were positively aged at 6 years and sexually identifiable in the field (one male fish and one female fish). Therefore, based on aging techniques and field observations, age at sexual maturity for Lake Mead razorback sucker is confirmed to occur at or around 6 years. This information further confirms the utility of the nonlethal fin-ray aging technique developed in previous study years, and highlights the importance of continued long-term data collection. As more fish are aged, we should realize other useful insights regarding survival, growth, and recruitment.

The majority of fish aged by BIO-WEST were spawned from 1974 to 1998. If Lake Mead followed the same pattern of razorback sucker abundance as other reservoirs (Minckley et al.

1991), a population would have developed in the late 1930s, the fish would have lived in the lake for 40–50 years, and then the population would have disappeared as a result of a lack of recruitment. As noted in the introduction of this report, a large population did develop in the late 1930s, and those fish should have disappeared around 1980 according to the pattern observed in other reservoirs. This suggests that recruitment that occurred in the late 1970s and perhaps the early 1980s was a result of spawning by the original population. The more recent recruitment in the late 1980s and 1990s may be the result of the fish that recruited in the late 1970s and early 1980s. Today's Lake Mead populations may consist of some older fish, many of which may have had parents in the original population with some from the relatively few fish that recruited in the later 1970s and early 1980s. Interestingly, recruitment has continued through 2002, and that trend is expected to continue.

The comparison of Lake Mead's elevation with the timing of razorback sucker recruitment (Figure 16) suggests that a change in the management of Lake Mead may be responsible for the apparent, sudden recruitment of razorback sucker. From the 1930s to 1963, Lake Mead was either filling (a time when initial recruitment likely occurred and created the original lake population of razorback sucker) or it was operated with a sizable annual fluctuation. The lake was drawn down approximately 100 ft in the mid 1960s as Lake Powell filled; since that time it has been operated with relatively small annual fluctuations but relatively large multiple-year fluctuations. We suspect that the drawdown of Lake Mead for filling of Lake Powell and a subsequent drawdown in the 1990s allowed terrestrial vegetation to become well established around the lake shoreline. The vegetation was then inundated as the lake rose, but (with small annual fluctuations) the vegetation remained intact for many years and provided cover in coves and other habitats that young razorback sucker may inhabit. During the pre 1970 period, vegetation could not become established because of the relatively large annual fluctuations. The presence of individual razorback sucker greater than 30 years indicates that limited recruitment may have occurred during the 1966–1978 period, during a time when lake elevations slowly rose to their highest levels (1978–1987) and the maximum amount of intact inundated vegetation probably existed in the lake.

Lake Mohave, where natural razorback sucker recruitment has not been documented, also has large annual fluctuations. Golden and Holden (2003) have shown that cover, in terms of turbidity and vegetation, is more abundant in Echo Bay and Las Vegas Bay than in other Lake Mead or Lake Mohave coves. This information leads to the hypothesis that low, annual fluctuations and large, multi-year lake elevation changes that promote the growth of vegetation around the lake, the inundation of that vegetation, and turbid conditions are the major reasons for razorback sucker recruitment in Lake Mead. However, not all Lake Mead coves have the proper conditions for cover (vegetation and turbidity) to develop. The timing of the change in Lake Mead management (pre- and post-Lake Powell) coincided with the final years of the original Lake Mead razorback sucker population, which likely resulted in some recruitment prior to the depletion of the original population.

Past population estimates for the Echo Bay and Las Vegas Bay populations indicate that there are 50–150 fish at each location, although no clear patterns are evident. Population estimates for spawning aggregates in Lake Mead were initiated during the early years of this study in order to ascertain whether sonic-telemetry-related surgical events would potentially threaten wild razorback sucker populations. Since that time, population estimates have continued throughout the duration of the study, mostly as an artifact of the initial goal to initiate sonic-tagging methodologies. Over the years, estimates have wide confidence intervals, yet each year fairly similar estimates have been reported (Holden et al. 1997, Holden et al. 1999, Holden et al. 2000a, Holden et al. 2000b, Holden et al. 2001, Abate et al. 2002, Welker and Holden 2003, Welker and Holden 2004, Albrecht and Holden 2005). The 2004–2006 estimate falls well within the ranges reported in past years' annual reports. However, because of the variability in terms of effort from one year to the next, coupled with very low capture probabilities (capture probabilities at Echo Bay were less than 3% [last 3 years] and less than 1% for the last 3 years at Las Vegas Bay) it is difficult to draw any meaningful conclusions from our estimates. Otis (1978) suggested that to obtain precise estimates, population estimates be made only when capture probabilities are at least 10%. Given the violation of many of the assumptions that are involved with closed model population estimation techniques currently used on Lake Mead, coupled with the nature of the data collected regarding the populations of razorback sucker on the lake, a more complex, open model may be a better option (Otis et al. 1978, Lettink and Armstrong 2003). Unfortunately, complex open model population estimation techniques require knowledge of factors such as births, deaths, immigration, and emigration; as such, efforts directed towards this end would be confounded by our ability to detect these processes (Lettink and Armstrong 2003). Acquiring such information would likely require considerable investments beyond the scope of this study. Therefore, continued reporting of population estimates should likely be discontinued, unless they are deemed important and useful by the various collaborating agencies.

Lastly, because the 2005 and 2006 collaborative, interagency efforts resulted in collecting a number of larval fish that could potentially be repatriated to Lake Mead in the future, BIO-WEST evaluated potential stocking site opportunities, as requested by agency collaborators. As outlined above, Driftwood Cove appears to be the best option for such efforts. Given the low yet steady recruitment patterns observed for Lake Mead razorback sucker (with opportunities for pulses in recruitment given certain lake conditions) we are hopeful that increased razorback sucker presence in Lake Mead will not only lead to additional opportunities to discover more about this unique species, but will also provide needed tools and key information that will benefit species recovery efforts throughout the historic range of the once-abundant razorback sucker.

RECOMMENDED WORK PLAN FOR 2006–2007

Since lake levels are expected to decline during the 2006–2007 field season, perhaps achieving the lowest levels observed during the course of this study, the general research objectives for the 11th study year include continuing to monitor the two populations of razorback sucker at Echo Bay and Las Vegas Bay, continuing to age individual razorback sucker from Lake Mead, and continuing to study razorback sucker use of the Overton Arm of Lake Mead. In addition to the continuation of general long-term data collections and monitoring efforts, emphasis will also be placed on continued evaluation of Driftwood Cove (if desired by collaborators), and increased efforts will be directed towards analyzing and summarizing data collected during past year's research efforts. Other specific objectives for 2006–2007 were also identified to provide answers to specific research questions. The following proposed work plan was developed to define specific objectives for the 11th study year.

Specific Objectives for the 11th Study Year

1. Continue tracking efforts associated with the active, sonic-implanted Floyd Lamb State Park razorback sucker in hopes of: (1) following spawning populations at the known spawning areas, particularly Las Vegas Bay, in order to evaluate whether any further shifts in spawning site selection occurs; (2) further investigating the new Fish Island spawning site to evaluate habitat use and help identify whether the Fish Island population functions as an independent spawning population or whether this is an extension of habitat use by the Echo Bay population; (3) identify whether habitats at Fish Island are used on an annual basis; and (4) potentially identify other, new spawning areas as dictated by tracking sonic-tagged fish.

2. Continue historical data collection including larval sampling, adult trammel netting, and fin-ray collection and aging techniques, with particular emphasis on PIT-tagging adult razorback sucker. This will further assist in determining if the Fish Island spawning area is a unique population, or it may assist in documenting exchange of fish between the Fish Island site and the Echo Bay spawning area and elucidate recruitment patterns at all areas. Trammel netting will be reduced to the spawning period to allow time and funds for other activities outlined below, as needed.

3. Continue to monitor Driftwood Cove as a potential site for future repatriation efforts, and identify other potential areas conducive to establishing new spawning populations throughout Lake Mead if/when warranted. Since numerous larval fish have been captured and are slated for potential, future repatriation efforts, we will continue to collaborate with interested parties in investigating various experimental stocking options and ideas. Methodologies for holding, imprinting, and assessing the survival rates and overall successes of potential stocking options may be investigated if/when desired by collaborators, and/or assistance may be rendered in the event of an actual repatriation/stocking effort (if/when requested) during the next field season. This effort

may entail further identification of potential stocking locations conducive to razorback sucker survival based on historical habitat usage and recruitment patterns displayed by Lake Mead razorback sucker. It could also involve developing repatriate monitoring methods to ascertain their success and integration with wild populations. Lastly, accomplishment of this objective could entail other actions as deemed necessary during future collaborative efforts if stocking efforts were pursued during the next study year.

4. Perform analyses and provide a comprehensive summary report of the Lake Mead razorback sucker data collected to date. Various investigations of the long-term database will be performed and included in the 2006–2007 annual report to summarize the knowledge obtained to date. Recommendations will be provided pertaining to potential options, needs, and strategies for future research, including ideas for monitoring or repatriation efforts, as deemed applicable.

Note

In addition to this annual report, we are preparing a companion report that outlines a monitoring plan for Lake Mead razorback sucker, in response to requests received during the compilation of last year's annual report. The companion report will draw inferences from the data collected to date regarding actions, methodologies, specific locations, and important dates conducive to the capture of razorback sucker of various life stages in Lake Mead. These data can be used under a variety of future habitat conditions and by various user groups.

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